

Preface

The frame approach for representing knowledge (i.e., collection of frames are linked together into frame-system) has been suggested by Marvin Minsky. In this approach, the frame corresponds to a data structure. In general, it is possible to consider the following three-component system: initial data/information, problem (s) (and corresponding models), and algorithm (or interactive procedure). For many complex applied problems, it is reasonable to examine special composite frameworks (i.e., composite solving schemes) consisting of problems (and corresponding models), which are interconnected/linked (e.g., by preference relation). For example, a basic simplified framework for data processing can be described as follows:

- (a) analysis of input data/information and preliminary processing;
- (b) processing; and
- (c) analysis of results.

Another example of a framework is well-known in decision-making. Herbert A. Simon has suggested his framework for rational decision-making (choice problem): (i) the identification and listing of all the alternatives, (ii) determination of all the consequences resulting from each of the alternatives, and (iii) the comparison of the accuracy and efficiency of each of these sets of consequences. A modified version of this decision-making framework is the following:

Stage 1. Analysis of the examined system/process, extraction of the problem.

Stage 2. Structuring of the decision-making problem:

- 2.1 generation of an alternatives set,
- 2.2 generation of criteria for evaluation of the alternatives and generation of a scale for each criterion.

Stage 3. Obtaining the initial information (estimates of the alternatives, preferences over the alternatives).

Stage 4. Solving process to obtain the decision(s).

Stage 5. Analysis of the obtained decision(s).

Now there exists a trend to design, to describe, and to use a set of basic typical engineering (technological) frameworks (i.e., typical composite combinatorial solving schemes), which can be considered as basic standard blocks in systems research/design and in systems education (engineering, computer science, applied mathematics).

In recent decades, modular approaches have been used in all engineering domains. Thus, many systems can be designed (composed) from basic modules (e.g., software engineering, computer engineering, information engineering, method engineering, protocol engineering, industrial engineering). Evidently, special combinatorial methods have to be studied and applied for system analysis/design at all stages of the system life cycles. The methods can have the following structure types: series, parallel, series-parallel, cascade-like. Here, the following basic problems are very important: (1) partitioning the initial problem (or partitioning the examined system), (2) solving the local problems, and (3) aggregation of solutions for the local problems above into the global system solution.

The material of this book enhances the materials of the previous author's books: "Composite Systems Decisions", Springer, 2006; "Combinatorial Engineering of Decomposable Systems", Springer, 1998. The book contains an author's attempt to examine a new

"Decision Support Technology Platform for Modular Systems"

as a set of typical combinatorial engineering frameworks for hierarchical modular systems (with hierarchical structures). This approach is based on the following five-layer architecture:

Layer 1. Basic combinatorial optimization problems (e.g., knapsack problem, multiple choice problem, multicriteria ranking/selection, clustering, minimum spanning tree problem, minimum Steiner tree problem, clique problem).

Layer 2. Complex (e.g., multicriteria) combinatorial optimization problems (e.g., multicriteria knapsack-like problems, multicriteria multiple choice problem, multicriteria Steiner tree, morphological clique problem, design of multilayer network topology).

Layer 3. Basic support frameworks (e.g., hierarchical design, aggregation of structures, restructuring of knapsack problem, restructuring of multiple choice problem).

Layer 4. Combinatorial engineering frameworks (consisting of a set of linked combinatorial problems) (e.g., hierarchical system modeling, design, evaluation, detection of bottlenecks, improvement, design of trajectory, combinatorial evolution, and forecasting).

Layer 5. Applied combinatorial engineering frameworks (e.g., modeling, design and improvement of system components for information-communication systems).

Note, engineering system design/synthesis can be considered/implemented on the basis of various methods, for example: design principles and systematic invention, general design theory as theory of knowledge, theory of technical systems, knowledge operations (reasoning, etc.), prototype-based design, morphological analysis, design catalogues based methods, system configuration design

based on AI methods, TRIZ (the Altshullerian approach to solving innovation problems), synthesis based on function-means trees, and synthesis of system topology using genetic programming. In this book, basic standard combinatorial engineering (technological) frameworks for modular systems are systematically described while taking into account the system life cycles (i.e., layer 4 above):

Framework 1. Design of system hierarchical model.

Framework 2. Combinatorial synthesis (“bottom-up” process for system design).

Framework 3. System evaluation (for system parts/components, for whole system).

Framework 4. Detection of system bottlenecks (e.g., by system elements, by compatibility of system elements, by system structure).

Framework 5. System improvement (redesign, upgrade, extension).

Framework 6. Multistage design (design of system trajectory).

Framework 7. Combinatorial modeling of system evolution/development and system forecasting.

The material extends previous author’s publications by the following ways:

- (a) description of hierarchical structures and their design,
- (b) description of system bottlenecks and approaches to their detection,
- (c) description and usage of new interval multiset estimates,
- (d) special description of system configuration based on combinatorial optimization,
- (e) description of combinatorial synthesis based on interval multiset estimates for system components,
- (f) description of special procedures for aggregation of modular solutions,
- (g) brief description of a new restructuring approach in combinatorial optimization, and
- (h) a set of various new applied examples for some parts of information technology (e.g., electronic shopping, Web-based system, integrated security system, telemetry system, wireless sensor, communication protocol, and standard for multimedia information).

The applied examples are based on the usage of the suggested combinatorial engineering frameworks including new methods above (e.g., interval multiset estimates, aggregation of structured solutions, system design, and system improvement). Generally, the suggested material corresponds to modular systems engineering in the field of information technology, but suggested approaches (frameworks) can be successfully applied in many domains (engineering, computer science, applied mathematics, management, social engineering).

The book consists of two parts:

The first part of the book (*Basic Combinatorial Engineering Frameworks*) involves the following: description of basic hierarchical system structures and basic standard combinatorial engineering frameworks (i.e., hierarchical system modeling, combinatorial synthesis, system evaluation, detection of system bottlenecks, system improvement, design of system trajectory, combinatorial system evolution, and

forecasting). Here, our version of morphological design approach plays a central role. In addition, a special attention is targeted to system configuration problems.

The second part of the book (*Applications in Information-Communication Systems*) contains the following real-world applied examples: description of applications (composite solving strategy for multicriteria ranking, electronic shopping of composite product, Web-based system, integrated security system, connection of end-users and access points in communication network, telemetry system, MPEG-like standard for multimedia information processing, wireless sensor, ZigBee communication protocol, management system for smart homes). In each applied example above, several combinatorial engineering frameworks are used, for example: (a) hierarchical system modeling, system design, system improvement, (b) hierarchical system modeling, system design, combinatorial system evolution and forecasting. The applications described can be used as a set of basic analogues (prototypes) for various applied domains.

In general, the book can be considered as an information and operation environment for hierarchical modular systems: combinatorial modeling, processing (design, evaluation, improvement, forecasting, etc.). In fact, this material corresponds to a “combinatorial ABC-book” for modular systems and/or for decision-making based on composite decisions (composite alternatives).

A preliminary version of this book was published as an electronic book in Russian:

Mark Sh. Levin, Decision Support Technology for Modular Systems. Electronic book, 2013 (in Russian); <http://www.mslevin.iitp.ru/Levin-bk-Nov2013-071.pdf>

This may be of interest to Russian-language readers.

The suggested book is oriented to applied researchers, students, and practitioners in many domains. Concurrently, the material will be of interest to various scientists (e.g., computer scientists, mathematicians, economists, social engineers). In addition, the book can be used as a useful text for some educational courses (e.g., systems engineering, system design, life cycle engineering, engineering design, combinatorial synthesis) at various levels: senior undergraduate level (a compressed version), graduate/Ph.D. levels, and for continuing education. The material of the book will be useful for modular curriculum design including the design of individual student educational programs.

Moscow, June 2014

Mark Sh. Levin



<http://www.springer.com/978-3-319-09875-3>

Modular System Design and Evaluation

Levin, M.S.

2015, XXI, 473 p. 405 illus., Hardcover

ISBN: 978-3-319-09875-3