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Note on Decision Support Platform for Modular Systems

Mark Sh. Levin

Institute for Information Transmission Problems RAS, Moscow, Russia
email: mslevin@acm.org
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Abstract—This methodological paper addresses a glance to a general decision support platform technology for modular systems (modular/composite alternatives/solutions) in various applied domains. The decision support platform consists of seven basic combinatorial engineering frameworks (hierarchical system modeling, system synthesis, evaluation, detection of bottleneck, improvement/extension, multistage design, combinatorial evolution and forecasting). The engineering frameworks are based on decision support procedures and combinatorial optimization problems (e.g., multicriteria selection/sorting, clustering), combinatorial optimization problems (e.g., knapsack, multiple choice problem, clique, assignment/allocation, covering, spanning trees), and their combinations. The following is described: (1) general scheme of the decision support platform technology; (2) brief descriptions of modular (composite) systems (or composite alternatives); (3) trends in moving from choice/selection of alternatives to processing of composite alternatives which correspond to hierarchical modular products/systems; (4) scheme of resource requirements (i.e., human, information-computer); and (5) basic combinatorial engineering frameworks and their applications.

KEYWORDS: decision support, platform technology, modular systems, systems engineering, engineering frameworks, combinatorial optimization

1. INTRODUCTION

In recent years the significance of modular products/systems and corresponding product families (and/or product lines) has been increased (e.g., [12–14, 33, 43, 61, 62]). This short methodological paper focuses on modular systems, their hierarchical modeling and seven typical engineering combinatorial frameworks (Fig. 1) [43].

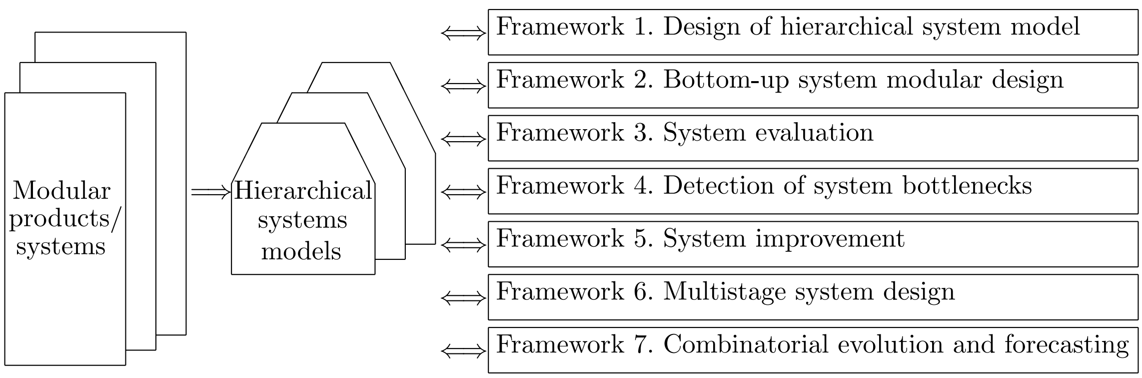

Fig. 1. Modular systems and basic combinatorial frameworks

The simplified scheme of the described decision support platform for modular systems is shown in Fig. 2. Some basic research directions in the fields of modularity and modular systems are briefly pointed out in Table 1 (e.g., mechanical systems, manufacturing systems, robots, software systems, computing systems, electronic systems, Web-based systems, communication protocols, control systems). Fig. 3 depicts a traditional scheme of product platform efforts for a certain product domain (e.g., buildings, software, manufacturing systems, aerospace systems, ships, mechatronics systems, computing systems, etc.) [57, 61, 62]. Here, a general decision support platform technology is briefly described that can be used for many engineering/management domains (Fig. 4) [40, 43]. The material is based on preliminary electronic preprint [42].

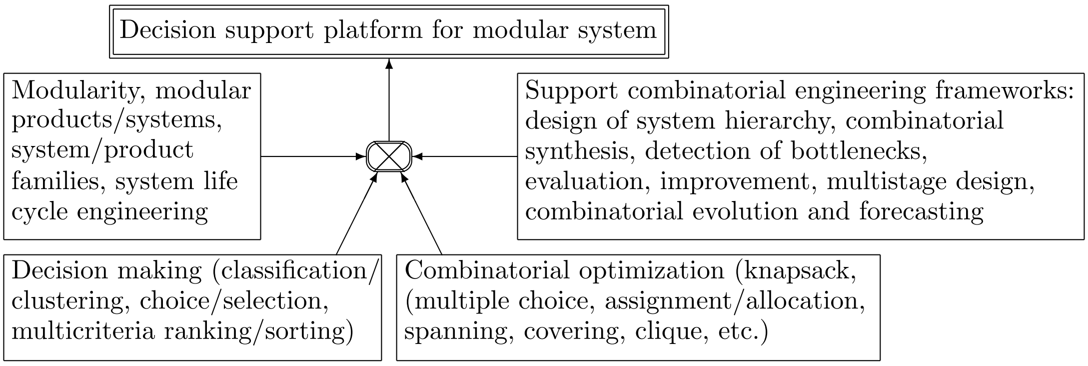

Fig. 2. Scheme of decision support platform for modular systems

Table 1. Basic research directions in modularity/modular systems

Nom.	Research direction	Some sources
1.	Modularity	[1, 2, 6, 16, 25, 32, 48]
2.	Modular products/systems	[12, 27, 32–34, 39, 40, 43, 53]
3.	Modularity and commonality research	[6, 17, 19, 21, 23, 26, 40]
4.	Products/systems configuration	[10, 11, 20, 39, 40, 43, 49, 50, 59, 63–67, 69]
5.	Reconfiguration, reconfigurable systems	[3–5, 8, 9, 15, 18, 38–40, 43]
6.	Adaptable design of products/systems	[15, 30, 35, 47, 68]
7.	Design of products/systems for variety	[21, 22, 48, 55]
8.	Product families	[11, 13, 17, 18, 23, 29, 33, 40, 62]
9.	Product platforms	[11, 14, 28, 29, 33, 36, 37, 48, 51, 57, 61, 62]
10.	Approaches to general decision support platform	[11, 20, 42, 43, 59, 67, 69]

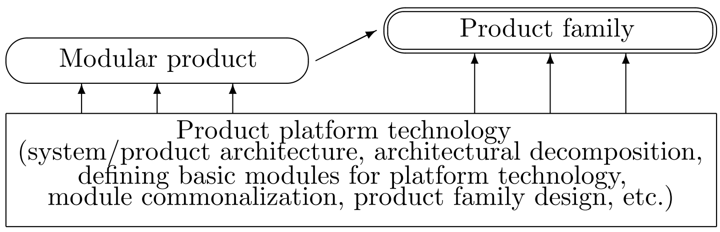

Fig. 3. Traditional scheme of product platform technology

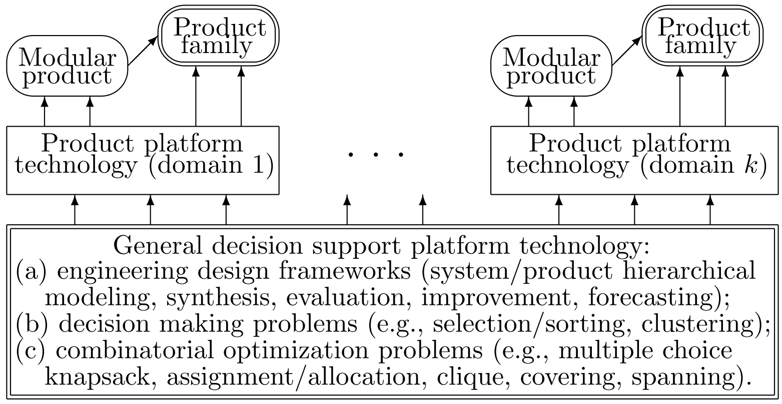

Fig. 4. General decision support platform for modular systems

2. SCHEME OF GENERAL DECISION SUPPORT PLATFORM

An extended scheme of the proposed general decision support platform technology is shown in Fig. 5. Here, two support layers of decision making and combinatorial optimization problems/models are used: (i) basic problems, (ii) composite problems.

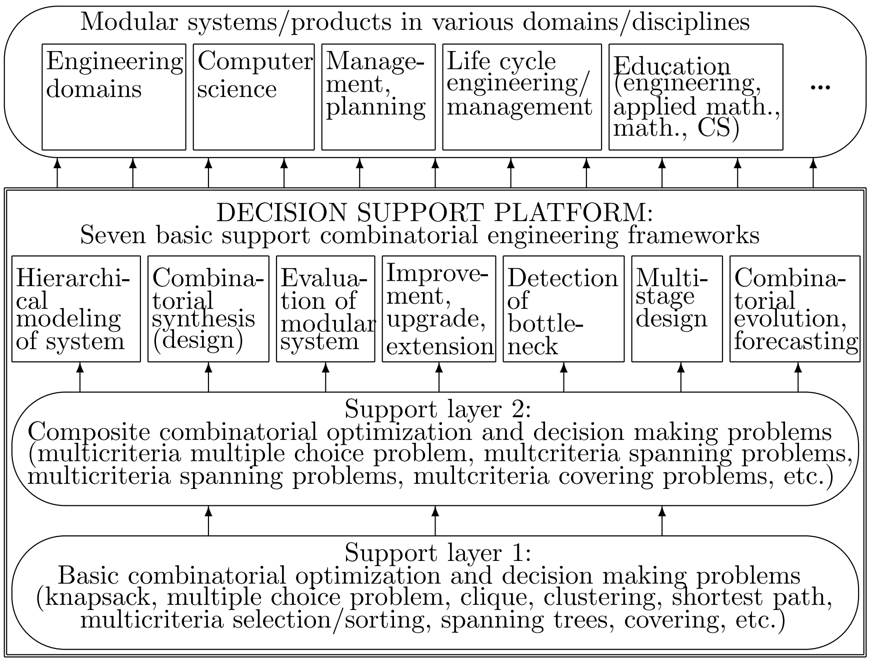

Fig. 5. Scheme of general decision support platform technology

3. TOWARDS HIERARCHICAL MODELING OF MODULAR SYSTEMS

In general, knowledge representation in product design systems is systematically studied in [7,31]. Here, modular systems or corresponding (modular/composite alternatives/solutions) are examined as the following (i.e., system configuration) (e.g., [39, 40, 43]: (a) a set of system elements (components, modules), (b) a set of system elements and their interconnections (i.e., a special structure over the system elements, e.g., hierarchy, tree-like structure). Fig. 6 depicts a composite (modular) system, consisting of n components/modules (and corresponding three design alternatives (DAs) for each component/module).

The system composition problem can be based on various approaches (e.g., logical methods, artificial, intelligence techniques combinatorial models) (e.g., [11, 49, 50, 59, 64, 66, 67]. In the author materials, morphological design as multiple choice problem or morphological clique problem (while taking into account compatibility between the selected DAs) is used for the composition problem (as combinatorial synthesis) [39, 40, 43]. Mainly, the composition problem plays the central role in decision support platform.

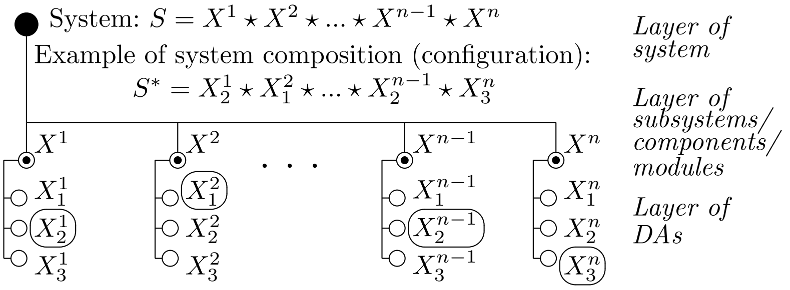

Fig. 6. Illustration for composite (modular) system

Fig. 7 illustrates the system composition for a four-component system while taking into account compatibility of DAs (concentric presentation).

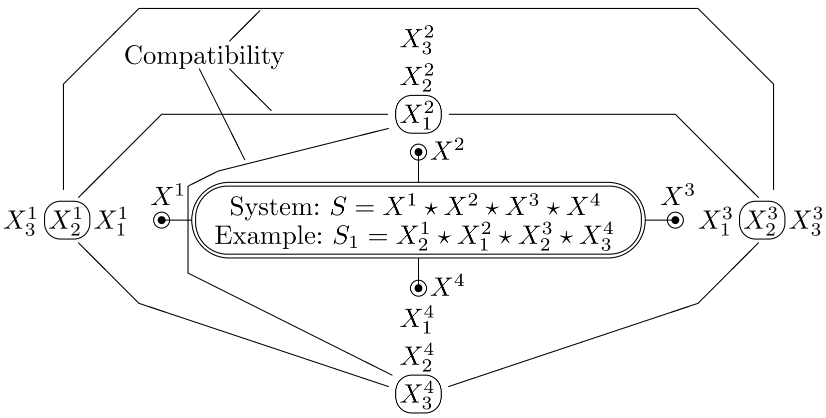

Fig. 7. Concentric presentation of system composition

In the case of DAs, the following information is considered (i.e., morphological system structure) (e.g., [39, 40, 43]: (a) estimates of DAs (e.g., vector estimates, ordinal estimates, interval multiset estimates), (b) estimates of compatibility between DAs of different system components (e.g., ordinal estimates, interval multiset estimates).

Further, two illustrations are presented: (i) hierarchical (tree-like) system model (Fig. 8) and (ii) hierarchical system model with common modules for subsystems (Fig. 9).

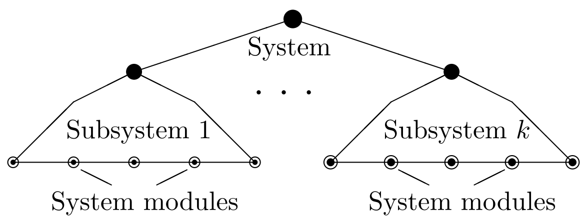

Fig. 8. Hierarchical (tree-like) system model

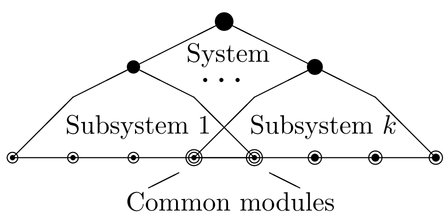

Fig. 9. Common modules for subsystems

Approaches to product families analysis, modeling and design have been described in [62]. A brief illustrative structural description of several types of product families is presented in [40]. A structural illustrative example of multi-product system (i.e., three-product family) with four common modules is shown in Fig. 10: $F = P' \star P'' \star P'''$. The set of 8 basic modules is: U, V, X, Y, Z, H, C, D. For each module above, a set of corresponding DAs (i.e., modifications) is pointed out (Fig. 10). The common modules are: X, Y, Z, H. Examples of product compositions are (Fig. 10): (a) $\{P'_1, P'_2\}$, (b) $\{P''_1, P''_2, P''_3\}$, (c) $\{P'''_1, P'''_2\}$.

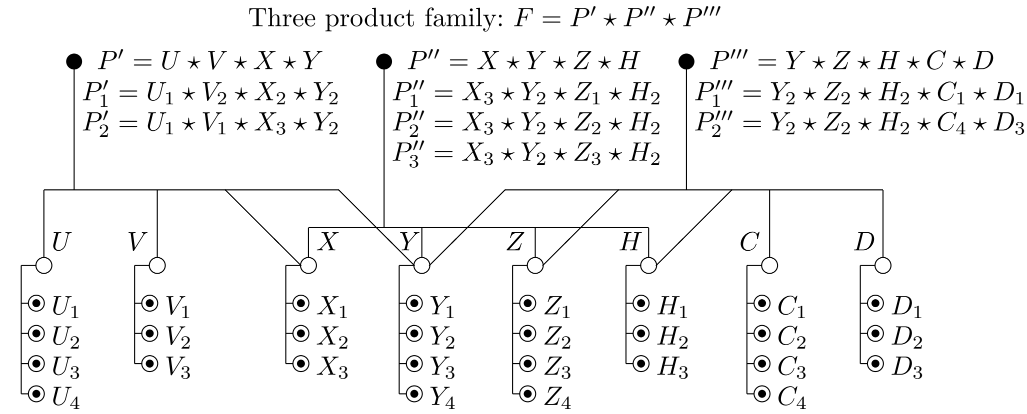

Fig. 10. System of product family (with common module set)

4. DECISION PROBLEM TREND FROM ALTERNATIVE TO COMPOSITE ALTERNATIVE

Fig. 11 depicts a contemporary decision making trend that consists moving process from alternative(s) to composite alternative(s) (i.e., composite systems) [39, 40, 43].

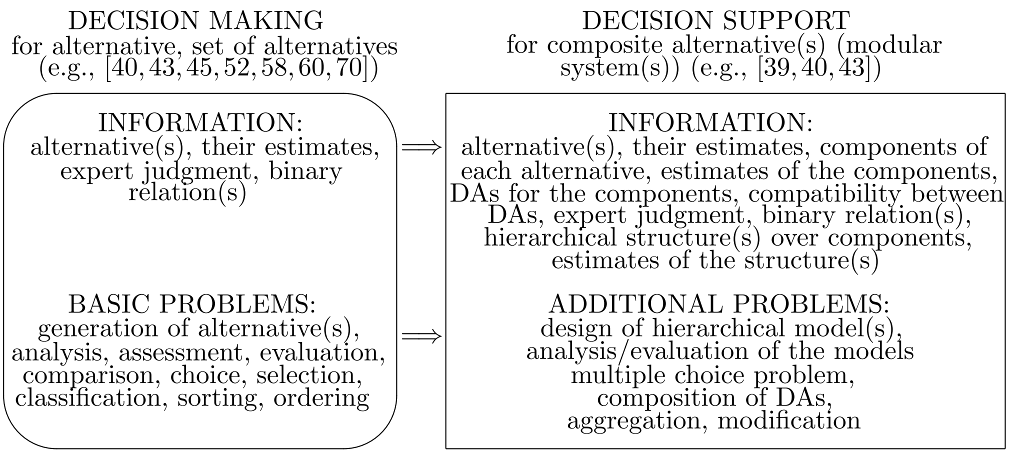

Fig. 11. Moving from alternative(s) to composite (modular) alternative(s)

Evidently, the decision problems became to be more complicated by several directions, for example:

(a) hierarchical structures (models) of composite alternatives and their processing (design of hierarchical structure/model, evaluation, comparison, modification, aggregation);

(b) components of each composite alternative and DAs for each component (including assessment and evaluation of the DAs), various approaches to assessment and evaluation of compatibility between DAs for alternative components.

In addition, it is reasonable to point out basic types of resources and corresponding kinds of resource requirements, i.e., human resources, information-computing requirements (Fig. 12).

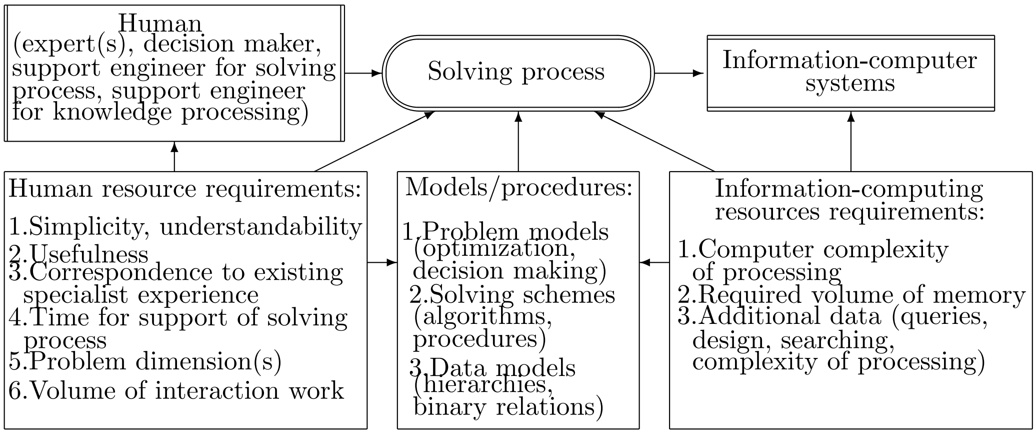

Fig. 12. Scheme of resource requirements

5. SUPPORT PROBLEMS/FRAMEWORKS AND APPLICATIONS

Seven support combinatorial engineering frameworks for modular systems (composite alternatives) have been suggested by the author (e.g., [40, 43]):

1. Design of hierarchical system model(s) (i.e., tree-like structures) [43]:

2. Morphological system design (combinatorial synthesis) based on hierarchical multicriteria morphological design (HMMD) approach (a hierarchical extension of morphological analysis while taking into account ordinal estimates of DAs and their compatibility) [39, 40, 43].

3. Evaluation of hierarchical modular system [39, 40, 43].

4. Detection of system bottlenecks [43].

5. System improvement/extension [39, 40, 43].

6. Multistage system design (design of system trajectory) [43].

7. Combinatorial system evolution and forecasting [43, 46].

Table 2 contains some applied examples for the combinatorial engineering frameworks above.

In the case of grouping the application examples by large discipline domains (Fig. 5), the following groups for application examples are obtained:

1. Engineering domains: control engineering (management system for smart homes) [43]; communication engineering: GSM system, standard for multimedia information processing [43], protocol engineering (communication protocol ZigBee) [43], generations of wireless systems [46]; sensor/telemetry systems [43]; concrete technology [40]; civil engineering (building from the viewpoint of earthquake engineering) [40].

2. Computer science: software engineering [40], information systems [39], configuration of applied Web-based information systems [43], composite retrieval [39, 43], problem solving strategies [43].

3. Management, planning: geological planning [39], investment [39], medical treatment [40, 43].

4. Life cycle engineering/management: concrete technology (design, manufacturing, transportation, utilization [40].

5. Education (engineering, applied mathematics, CS): design and combinatorial modeling of modular courses on system design [39, 40, 43], student trajectory planning [39].

Table 2. Applications of combinatorial engineering frameworks

Nom.	Support combinatorial engineering framework	Some application(s)
1.	Hierarchical system modeling	Management system in smart home [43], communication protocol ZigBee [43], concrete technology [40], immunoassay technology [40], standard for multimedia [43], on-board telemetry system [43], medical treatment [40, 44], vibration conveyor [39], wireless sensor element [43], web-based information system [43], composite product in electronic shopping [43], building [40], generation of wireless communications [46], modular education courses [39, 43], series-parallel solving strategy (for multicriteria ranking) [43], student trajectory planning [39], integrated security system [43]
2.	Combinatorial synthesis (bottom-up modular design)	Modular software [40], management system in smart home [43], GSM communication network [43], wireless sensor element [43], on-board telemetry system [43], medical treatment [40, 44], vibration conveyor [39], concrete technology [40], immunoassay technology [40], web-based information system [43], communication protocol ZigBee [43], standard for multimedia [43], electronic shopping [43], generation of wireless communications [46], series-parallel solving strategy (for multicriteria ranking) [43], student trajectory planning [39], integrated security system [43]
3.	Hierarchical evaluation of system	Management system in smart home [43], wireless sensor element [43], vibration conveyor [39], concrete technology [40], building [40], immunoassay technology [40], medical treatment [40, 44], on-board telemetry system [43], communication protocol ZigBee [43], standard for multimedia [43], web-based information system [43], composite product in electronic shopping [43]
4.	Detection of system bottlenecks	Web-based information system [43], wireless sensor element [43], on-board telemetry system [43]
5.	System improvement/ extension	Management system in smart home [43], wireless sensor element [43], on-board telemetry system [43], building [40], generation of wireless communication systems [46]
6.	Multistage design (design of system trajectory)	Modular education courses [43], web-based information system [43], start-up team (trajectory) [43]
7.	Combinatorial evolution and forecasting	Modular education courses [43], web-based information system [43], Standard for multimedia [43], communication protocol ZigBee [43], generation of wireless communication systems [46], modular educational course [43]

6. CONCLUSION

This paper contains the author's glance to a general decision support platform technology for modular systems (i.e., composite/modular alternatives). Evidently, the decision support platform is an open system and can be extended, for example: (i) additional combinatorial optimization models (e.g., [24, 41, 54, 56]), (ii) additional composite combinatorial frameworks (e.g., [43]). It is reasonable to point out the following future research directions for the described decision support platform: *1.* the platform may be considered as a prospective tool for modular system design, evaluation, and maintenance; *2.* the platform may be interesting from the viewpoint of new decision support systems for composite (modular) alternatives; *3.* the platform is a significant direction for contemporary support systems in the field of system/product life cycle engineering/management; and *4.* the platform may be useful in educational processes. The author states that there is no conflict of interest.

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