TOWARDS K-SET FRAMEWORKS IN EDUCATION

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Abstract: The paper addresses k-set frameworks as a basic for education (teaching and students projects). The material consists of the following: (i) scheme of designing a structural description for a new domain (as a new .world.), (ii) k-set problems (one-set problems as decision making/ordering, two-set problems as assignment/allocation, etc.), (iii) problems of hierarchy design and restructuring/reconfiguration (hierarchical clustering, spanning trees, reconfiguration of spanning trees), (iv) combined frameworks (decision making framework, framework for system testing/maintenance, planning in distributed computer environment), and (v) educational scheme based on k-set problems/frameworks.

1 INTRODUCTION

In recent decades, the significance of complex systems and complex problems in education has been increased. Thus, contemporary student education has to lead to multidimensional system thinking including the following: (1) multi-component systems, (2) multi-stage system life cycle, (3) multicriteria/multiparameter approaches, (4) multilevel scales for evaluation, (5) multi-method (multi-disciplinary) approaches, (6) multi-model approaches, and (7) structural approaches and methods. In general, it is reasonable to point out that problem structuring phase is often a crucial one in problem life cycle (i.e., problem description, problem statement, problem solving, etc.). In recent years, problem structuring methodology is intensively studied (Keys, 2007; Rosenhead, 2006; White, 2009; Wiek and Walter, 2009).

k-set frameworks were suggested for structuring and formulation of complex multi-component applied domains in (Levin, 2010b). Here k-set frameworks are considered as a basic for education (teaching and students projects). Mainly the material has a discussion character. The following is considered:

(i) scheme of designing a structural description for a new domain (as a new “world”),

(ii) k-set problems (one-set problems as decision making/ordering, two-set problems as assignment/allocation, etc.),

(iii) problems of hierarchy design and restructuring/reconfiguration (hierarchical clustering, spanning trees, reconfiguration of spanning trees),

(iv) combined frameworks (decision making framework, framework for system testing/maintenance, planning in distributed computer environment), and

(v) educational scheme based on the problems/frameworks above.

2 DESIGN OF A NEW WORLD

A basic preliminary stage of problem structuring/formulation (design of a new “world”) consists in the following:

Stage 1. Revelation of basic concepts (e.g., goals, objects, resources).

Stage 2. Revelation of relations (relations over the concepts at the same concept set, relations over the concepts of different concept sets).

Stage 3. Formulation of main problems (e.g., resource assignment, planning, scheduling).

Figure 1 depicts the design approach to a new “world” including concept sets and relations. Further, it is possible to consider solving scheme, solving process, and analysis of results.

3 K-SET PROBLEMS

Basic one-set problems are depicted in Figure 2. Here the problem set consists of basic decision making problems (choice, ranking/sorting, clustering) (Levin, 1998; Levin, 2006a; Roy, 1996; Simon and Newell,

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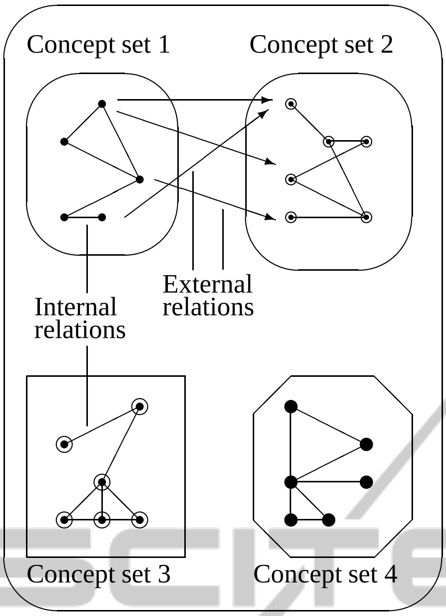

Figure 1: Illustration for new “world”.

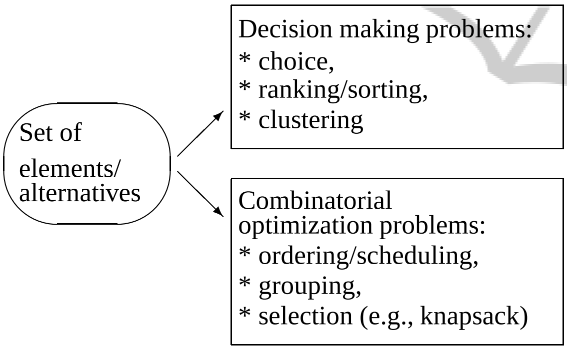

Figure 2: One-set problems.

1958; Zapounidis and Doumpos, 2002) and combinatorial optimization problems as ordering/scheduling, grouping, knapsack (i.e., selection of a subset) (Garey and Johnson, 1979; Levin, 1998).

Generally, a set of two-set problems involves assignment/allocation problem, graph coloring (Figure 3) (Garey and Johnson, 1979; Levin, 1998; Levin, 2009a).

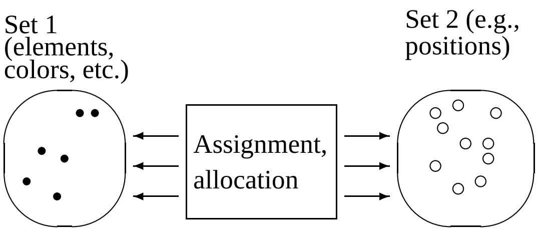

Figure 3: Illustration for two-set problems.

Three-set problems are based of 3-matching (Figure 4) (Garey and Johnson, 1979; Levin, 2009a). In addition, it may be reasonable to point out the following kind of problem (scheduling of assignment results): assignment problem (e.g., workers/tasks into work positions/processors) at each time interval. Here the set of time intervals corresponds to the third set.

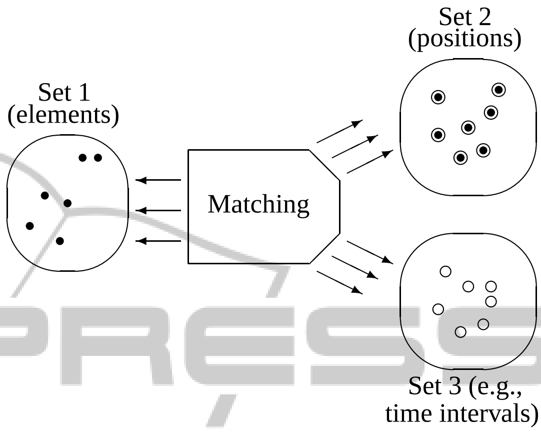

Figure 4: Illustration for three-set problems.

4 HIERARCHY AND RESTRUCTURING

In recent decades problems of “design of hierarchy” over set element became to be a critical part of many real world applications. This kind of problem corresponds to revelation of binary relation(s) (as hierarchy) over a set of element. Note traditional decision making problems (i.e., choice, ranking) and some combinatorial optimization problems (e.g., knapsack, multiple choice problem) may be considered as “design of hierarchy” because they are targeted to resultant binary relations over alternatives/elements. Hierarchical clustering (agglomerative algorithms) leads to a tree-like structure (or a hierarchy) over a set of initial elements (Figure 5). The agglomerative algorithm implements a “Bottom-Up” solving scheme.

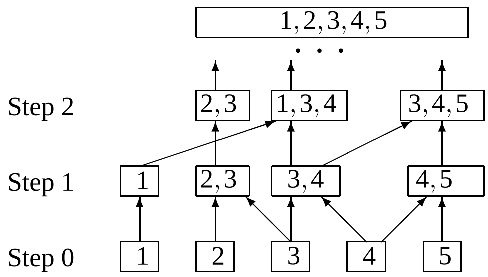

Figure 5: Scheme of agglomerative algorithm.

Evidently, the examined problem may be based on ex-pert judgment as well.

Problems of "spanning trees" (e.g., minimal spanning tree problem, Steiner tree problem, multicriteria versions of the problems) can be considered as a special class of the examined problems (i.e., "design of hierarchy"). Figure 6 illustrates the problems.

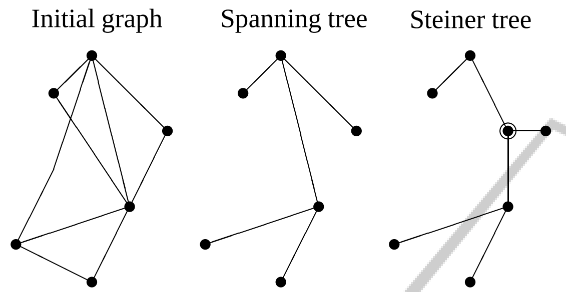

Figure 6: Illustration for spanning trees.

A prospective problem kind consists in restructuring (reconfiguration, resolving) of a structured problem solution (e.g., (Levin, 2009a)). This problem may be used for the following basic combinatorial optimization problems as a change of a solution (e.g., subset, structure): (i) knapsack problem, (ii) multiple choice problem, (iii) assignment, (iv) graph coloring, (v) vertex covering, (vi) spanning tree problem (Figure 7), (vii) Steiner problem (Figure 8). Here it is necessary to take into account a cost of solution changes (e.g., removal of a Steiner node).

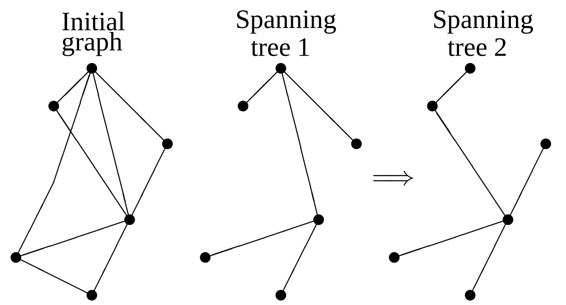

Figure 7: Restructuring of spanning tree.

Let P be a combinatorial optimization problem with a solution as structure S (i.e., subset, graph), A be initial data (element parameters, etc.), $f(P)$ be objective function(s). Thus $S(A)$ will be a solution of initial data A, $f(S(A))$ will be the corresponding objective function. Further, let A^0 be initial data at an initial stage, $f(S(A^0))$ will be the corresponding objective function, A^1 be initial data at next stage, $f(S(A^1))$ will be the corresponding objective function.

As a result, the following solutions can be considered: (a) $S^0 = S(A^0)$ with $f(S(A^0))$ and (b)

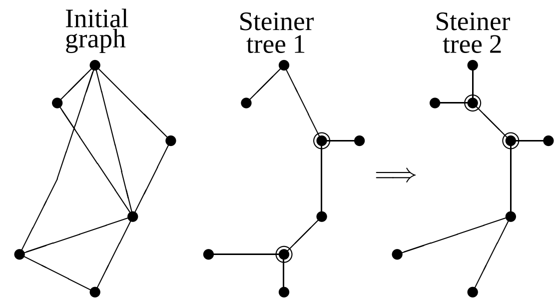

Figure 8: Restructuring of Steiner tree.

$S^1 = S(A^1)$ $f(S(A^1))$. In addition it is reasonable to examine a cost of changing a solution into another one: $c(S^\alpha \rightarrow S^\beta)$. Let $\rho(S^\alpha, S^\beta)$ be a proximity between solutions S^α and S^β, for example, $\rho(S^\alpha, S^\beta) = |f(S^\alpha) - f(S^\beta)|$. Note function $f(S)$ is often a vector function. Finally, the restructuring problem can be examine as follows (a basic version):

Find a solution S^ξ while taking into account the following:

(i) $c(S^0 \rightarrow S^\xi) \rightarrow \min$ and (ii) $\rho(S^\xi, S^1) \rightarrow \min$ (or constraint).

Figure 9 illustrates the suggested restructuring problem.

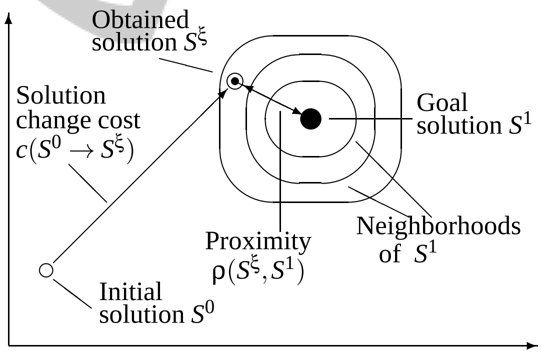

Figure 9: Illustration for restructuring problem.

5 COMBINED FRAMEWORKS

In recent sixteen years, the author and his students have used several typical combined frameworks, for example:

(i) hierarchical morphological design of modular systems,

(ii) improvement of networked systems (including improvement of system components, improvement of interconnection among system components, improvement of system structure), and

(iii) planning of marketing (including groups of products, marketing strategies, typical customer groups).

Here three combined problem solving frameworks are illustrated.

5.1 Decision Making

A scheme of decision making process is depicted in Figure 10 (Levin, 2006a). The scheme is an important basis for teaching of decision making engineering. On the other hand, the scheme is a reference example of a generalized applied domain. Here the following sets are basic ones: (i) criteria (and their importance, relations over them), (ii) alternatives (and their estimates upon criteria or relations), (iii) solving methods/techniques, (iv) experts, and (v) reference decisions.

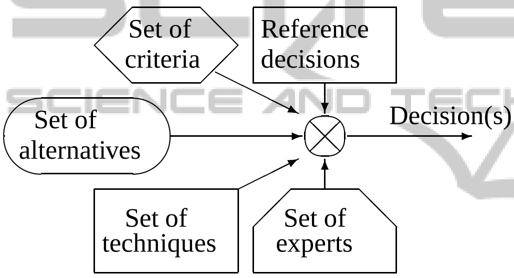

Figure 10: Decision making framework.

5.2 System Testing/Maintenance

Stages of system testing and system maintenance are significant parts of system life cycle. In the case of modular systems, planning of the stages above can be based on a multi-set framework (Levin and Merzlyakov, 2008) (Figure 11). Here the following sets are examined: (a) set of workers, (b) set of system components/parts, and (c) basic set of test/maintenance actions. Clearly, time intervals can be considered as well. Here two optimization problems are used: assignment/allocation (i.e., workers into system parts) and multiple choice knapsack problem (selection of actions while taking into account a total resource constraint).

5.3 Distributed Computing

Figure 12 illustrates planning in distributed computing environment that is based on the following sets: (i) set of computer servers (including relations over the servers), (ii) several sets of computing tasks (including relations over the tasks), (iii) time intervals. The main problem is:

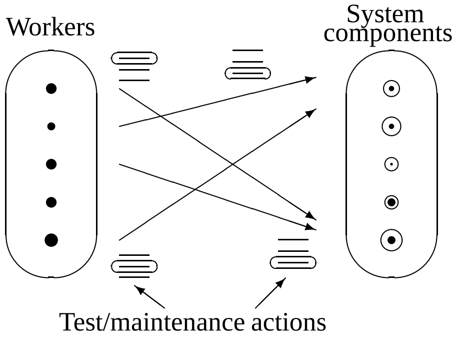

Figure 11: System testing/maintenance.

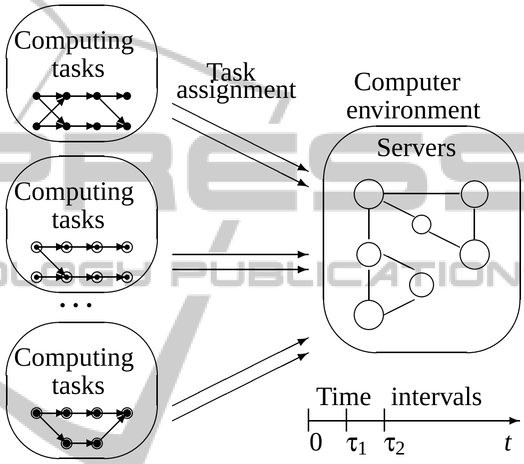

Figure 12: Planning for distributed computing.

Assign computing tasks into servers (for each time interval) while taking into account the following: (1) relations over the tasks, (2) resource requirements of each task, (3) relations over the servers, and (4) resources of each server.

In addition, other combinatorial problems are used, for example: grouping of tasks, selection/ranking of tasks and/or servers.

6 EDUCATIONAL SCHEME

Our generalized educational framework is based on a flow of k-set problems (Figure 13). The educational process is targeted to step-by-step examination of more and more complicated problems/models (i.e., one-set problems, two set problems, and etc.). Concurrently, students have to obtain the following information and skills:

(a) models and algorithm (algorithm schemes, solving procedures),

(b) real world applications (e.g., system design, management, maintenance) in various domains (computer systems, engineering, management, etc.).

In the best case, students can examine application problems in the filed of their interests/experience (e.g., communication systems, software engineering, information systems, web-based services, private life, sport).

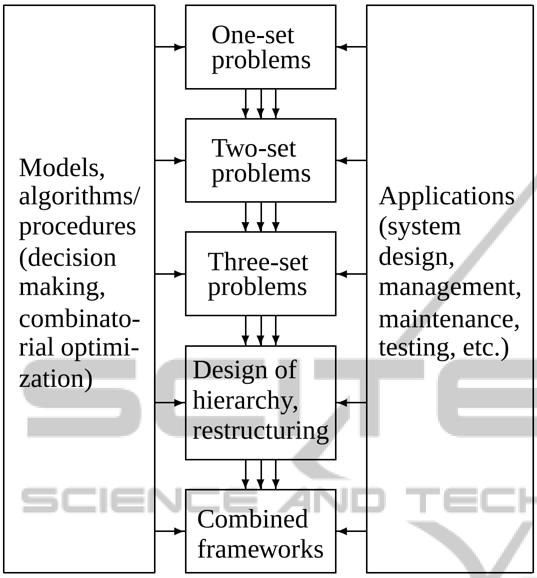

Figure 13: Generalized educational framework.

7 CONCLUSIONS

In the paper, k-set frameworks are considered as a basic for education (teaching and students projects). The material of the article is based on authors course and advising his undergraduate and graduate students: Moscow Inst. of Physics and Technology - State Univ., Faculty of Radio Engineering and Cybernetics (Levin, 2006b; Levin, 2009b; Levin, 2010a). Over ten students papers based on k-set problem frameworks were published (Table 1):

1. 2-set framework (multicriteria assignment, system upgrade based on multicriteria multiple choice problem),

2. 3-set framework (system testing, marketing),

3. frameworks for spanning trees (multicriteria Steiner tree problem, multicriteria Steiner tree problem with cost of Steiner vertices), and

4. framework for hierarchical system design.

In the future it may be reasonable to consider the following research directions:

(i) study and usage of the modified k-set frameworks and new kinds of the k-set frameworks;

(ii) consideration of the additional problem kinds (e.g., covering problems, graph coloring problems);

(iii) examination of various restructuring problems/models and their applications;

(iv) continuation of educational activity as student projects based on k-set frameworks;

Table 1: Students papers.

Kind of framework	References
1. 2-set framework (multicriteria assignment, system upgrade based on multicriteria multiple choice problem)	(Levin and Petukhov, 2010b) (Levin and Safonov, 2010) (Levin and Petukhov, 2010a)
2. 3-set framework (system testing, marketing)	(Levin and Merzlyakov, 2008) (Levin and Fimin, 2009)
3. Frameworks for spanning trees	(Levin and Nuriakhmetov, 2009) (Levin and Zamkovoy, 2010)
4. Framework for hierarchical system design	(Levin and Vishnitskiy, 2007) (Levin and Khodakovskii, 2007) (Levin and Sharov, 2009) (Levin and Fimin, 2010)

(v) usage of k-set problems and combined frameworks as a basis for students evaluation/classification; and

(vi) design of special computer-support environments based on k-set frameworks.

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