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# Extensions of Dynamic Programming for Combinatorial Optimization and Data Mining

Mikhail Moshkov

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# **Extended Abstract**

# Extensions of Dynamic Programming for Combinatorial Optimization and Data Mining

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**Abstract.** In contrast with conventional dynamic programming algorithms that return one solution, extensions of dynamic programming allows us to work with the whole set of solutions or its essential part, to perform multi-stage optimization relative to different criteria, to count the number of solutions, and to find the set of Pareto optimal points for bi-criteria optimization problems. The presentation is based on the results considered in three books published or accepted by Springer.

**Keywords:** Dynamic programming extensions · Bi-criteria optimization · Multi-stage optimization

The conventional dynamic programming algorithms for optimization problems include a structure of sub-problems of the initial problem, a way to construct a solution for a sub-problem from solutions of smaller sub-problems, and solutions for the smallest sub-problems. Such algorithms return only one solution.

In books [1–3] we consider extensions of dynamic programming that allow us (i) to make multi-stage optimization relative to a sequence of criteria, (ii) to describe the whole set of solutions or its essential part, (iii) to count the described solutions, and (iv) to construct the set of Pareto optimal points for a bi-criteria optimization problem. In this presentation, we discuss mainly results considered in the book [1] and mention some results presented in the books [2, 3].

In [1], we apply extensions of dynamic programming to the study of decision trees and rules for conventional decision tables with single-valued decisions, to the optimization of element partition trees for rectangular meshes which are used in finite element methods for solving PDEs, and to multi-stage optimization for such classic combinatorial optimization problems as matrix chain multiplication, binary search trees, global sequence alignment, and shortest paths.

In particular, for the decision trees, the applications of multi-stage optimization include the study of totally optimal (simultaneously optimal relative to a number of cost functions) decision trees for Boolean functions, improvements on the bounds on the depth of decision trees for diagnosis of constant faults in read-once circuits over monotone basis, computation of minimum average depth for a decision tree for sorting eight elements (a problem that was open since 1968), study of optimal reducts and

decision trees for modified majority problem, and designing an algorithm for the problem of reduct optimization.

The applications of bi-criteria optimization include the comparison of different greedy algorithms for construction of decision trees, analysis of trade-offs for decision trees for corner point detection (used in computer vision), study of derivation of decision rules from decision trees, and a new technique called multi-pruning of decision trees which is used for data mining, knowledge representation, and classification. The classifiers constructed by multi-pruning process often have better accuracy than the classifiers constructed by CART.

In [2], we generalize the considered tools to the case of decision tables with many-valued decisions. We also study inhibitory trees and rules, which instead of expressions “decision = value” use expressions “decision  $\neq$  value”. Inhibitory trees and rules can, sometimes, describe more information derivable from a decision table than decision trees and rules.

In [3], we apply the extensions of dynamic programming including multi-stage and bi-criteria optimization, and counting of optimal solutions to the following 11 known combinatorial optimization problems: matrix chain multiplication, global sequence alignment, optimal paths in directed graphs, binary search trees, convex polygon triangulation, line breaking (text justification), one-dimensional clustering, optimal bitonic tour, segmented least squares, matchings in trees, and 0/1 knapsack problem.

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