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On multi-objective optimization aided drawing of special graphs

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ABSTRACT

A special graph drawing problem related to the visualization of business process diagrams is considered. It is requested to find aesthetically looking paths between the given pairs of vertices of a grid, where the vertices represent the business process flow objects, and the paths represent the sequence flow. The sites of flow objects on the grid are fixed, and the sequence flow is defined. We state the problem of search for aesthetically looking paths as a problem of combinatorial multi-objective optimization, where the objectives correspond to the generally recognized criteria of aesthetics. To find a solution precisely, the algorithm of linear binary programming CPLEX was applied. For a faster solution, supposed for an interactive mode, a heuristic algorithm is developed. The experimental comparison of the mentioned algorithms is performed to substantiate the applicability of the latter.

1. Introduction

Graphs are very popular models of many research subjects. Graphical presentation of a problem is advantageous for heuristic perception and understanding of relations between the objects considered. On the other hand, many efficient algorithmic techniques are available to attack mathematically stated graph problems. Therefore graph models are especially useful where heuristic abilities of a human user in the formulation of a problem are combined with its algorithmic solution in the interactive mode. In the present paper we consider the graph models of business processes which, in the literature on the management of business processes, are called business process diagrams (BPDs). To be more precise, a problem of drawing aesthetically pleasing layouts of BPDs is considered. The research of this problem was motivated by the fact that the aesthetic layouts are not only well readable but also most informative and practical [1].

General rules for drawing BPDs are defined by the standards of Business Process Model and Notation (BPMN) [2]. These standards, however, leave sufficient freedom for choosing the techniques of BPD drawing that are most relevant to the supposed conditions of business process management. Here, as just like in a general graph drawing problem, special cases of the problem frequently cannot be solved by the straightforward application of the known methods and algorithms despite that many publications and algorithms are available. We cite [3]: Few algorithms are designed for a specific domain, and there is no guarantee that the aesthetics used for generic layout algorithms will be useful for the visualization of domain-specific diagrams. In the present paper, the methods for drawing BPDs are aimed at the application by the business process management consultants who advise managers of small and medium enterprizes planned to be established or undergoing the re-organization.

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We assume that the location of geometric shapes, that represent business process objects, is fixed on a plane, and a sequence flow is defined. The lines, that represent the sequence flow, should be drawn aiming to obtain an aesthetically pleasing layout. For the general concept of aesthetic graph drawing we refer to [1,3–8]. Here we reduce this problem to a combinatorial multi-objective optimization. Note that the shapes are either located interactively by a user or their location is computed by an appropriate algorithm, e.g., presented in [9].

The problem of visualization of a sequence flow is considered as a problem of combinatorial multi-objective optimization in [10], where the objectives correspond to the aesthetic criteria. The results of a psychological experiment, described in [10], substantiate the selection of aesthetic criteria that are most important for the potential users. The stated problem is attacked in [10] by a metaheuristic ant colony optimization algorithm. The solutions, found by means of that algorithm in reasonable time, were assessed as acceptable for applications. Nevertheless, the following reason motivates a further investigation: usually several solutions with the best value of each criterion were found, and the Pareto front consisted either of two or three solutions. Therefore a hypothesis seems likely that there exists a solution optimal with respect to all criteria, but it is not found by the metaheuristic algorithm used. To test that hypothesis all the global optima of the criteria in question should be found with a guarantee. To this end, we state the corresponding single-objective optimization problems in the form of binary–linear optimization, and apply the CPLEX algorithm [11] in their solution. A combination of CPLEX with the scalarization technique is also used to solve the multi-objective optimization problem in question. However, such a combination, although well suitable to solve small size problems, fails in the case of larger problems because of long computing time. A heuristic algorithm is proposed applicable to the problems of the size sufficient for applications.

The paper is organized as follows. In Section 2, we state the problem of drawing aesthetically pleasing BPDs as a problem of combinatorial multi-objective optimization. In Section 3, a binary–linear model of the considered problem is proposed which is used in Section 4 to formulate relevant optimization problems. In Section 5, two heuristic method aimed at the solution of the multi-objective optimization problem, stated in Section 2, are considered. Finally, we present the results of numerical experiments, and formulate conclusions.

2. On aesthetic drawing of BPD

A problem of the aesthetic BPD drawing is considered. An example of elementary BPD is presented on the left of Fig. 1. In the present paper, a special case is considered, namely, the problem of visualization of a sequence flow in BPD. In geometric terms, it is requested to draw paths that consist of horizontal and vertical line segments, and connect the given geometric shapes (circles, rhombuses and rectangles) in the plane. The shapes are located in "swim lines", at the centres of cells of a rectangular grid, and the paths are requested to consist of horizontal and vertical segments with the ends at circle markers, located on the boarders between "swim lines", as shown on the right of Fig. 1. In terms of the graph theory we are interested in the paths between the given vertices of a graph, defined by a rectangular grid of the type presented in Fig. 1. We search here for the paths with the minimum total length, minimum total number of bends, and minimum neighborship; we refer to [10] for a detailed discussion on the criteria of path desirability. The argumentation presented there substantiates the consideration of the problem of aesthetic drawing of BPDs by means of the methods for multi-objective graph optimization.

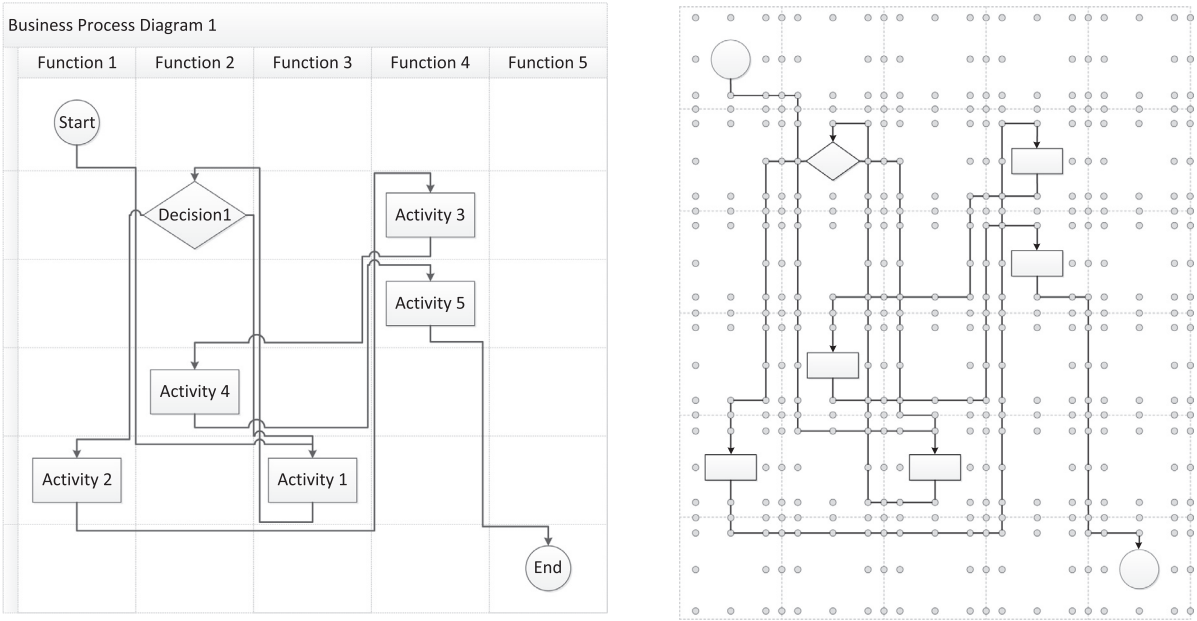

Fig. 1. An elementary example of BPD (on the left), and its grid model (on the right).