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Multi-objectives Tabu Search based algorithm for progressive resource allocation

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Abstract

Military course of action planning involves time and space synchronization as well as resource and asset allocation. A mission could be seen as a defined set of logical ordered tasks with time and space constraints. The resources to task rules require that available assets should be allocated to each task. A combination of assets might be required to execute a given task. The couple (task, resources) constitutes an action. This problem is formulated as a multi-objectives scheduling and resource allocation problem. Any solution is assessed based on a number of conflicting and heterogeneous objectives. In fact, military planning officers should keep perfecting the plan based on the Commander's criteria for success. The scheduling problem and resource allocation problem are considered as NP-Hard Problems [A. Guitouni, B. Urli, J.-M. Martel, Course of action planning: A project based modelling, Working Paper, Faculté des sciences de l' administration, Université Laval, Québec, 2005]. This paper is concerned with the multi-objectives resource allocation problem. Our objective is to find adequate resource allocation for given courses of action schedule. To optimize this problem, this paper investigates non-exact solution methods, like meta-heuristic methods for finding potential efficient solutions. A progressive resource allocation methodology is proposed based on Tabu Search and multi-objectives concepts. This technique explores the search space so as to find a set of potential efficient solutions without aggregating the objectives into a single objective function. It is guided by the principle of maximizing the usage of any resource before considering a replacement resource. Thus, a given resource is allocated to the maximum number of tasks for a given courses of action schedule. A *good allocation* is a potential efficient solution. These solutions are retained by applying a combination of a dominance rule and a multi-criteria filtering method. The performance of the proposed Pareto-based approach is compared to two aggregation approaches: weighted-sum and the lexicographic techniques. The result shows that a Pareto-based approach is providing better solutions and allowing more flexibility to the decision-maker.

Keywords: Tabu Search; Courses of action; Multi-criteria; Resources allocation; Pareto optimality

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1. Introduction

Most real-world optimization problems are multi-objectives in nature: several objectives should be considered at the same time. However, multi-objectives optimization problems (MOP) are very complex and the complexity besides the combinatorial aspect, comes from the fact that there is no single optimal solution for these problems, but rather a set of trade-offs called efficient solutions or Pareto-optimal solutions. In many multi-objectives planning situations, the most important challenge is to find efficient feasible solutions. Space and Time interdependent tasks are subject to resource constraints.

For instance, the course of action (COA) development stage of the military operational planning process (OPP) involves many Staff members. There is no doubt about the importance of the OPP as a fundamental problem solving process to guide a military staff in their thinking process with guidance from the Commander. The OPP is composed of five stages: initiation, orientation, COA development, plan development and plan review. The initiation stage starts with the reception of a mission statement or simply in anticipating of a new mission. In the orientation stage, the Staff begins the analysis and definition of the mission, prepares the planning guidance and describes Commander's intent and the desired end state of the operation. The Commander's guidance and intent help the staff to focus on the development of comprehensive and flexible plans within the allocated time. These COAs "should answer the fundamental questions of when, who, what, where, why and how". Each COA should be suitable, feasible, acceptable, exclusive and complete. A good COA prepares the force for future operations and provides flexibility to meet unforeseen events during its execution. The "who" in a COA does not specify individual units, but rather uses generic assets and capabilities. During the COA development stage, staff analyzes the relative combat power of friendly and enemy forces, and generates comprehensive COAs. The decision stage is based on the analysis and comparison of the proposed COAs, and the primary approach used in this analysis is war-gaming. Plan approval and review consists of a choice of the best COA according to the Commander's beliefs and estimates.

The COA development stage involves the entire staff. They should identify the assigned and implied tasks to perform a given mission. These tasks can be decomposed into sub-tasks. Then, planners should allocate available resources and capabilities to the tasks. Synchronizing COA requires scheduling starting and ending times of all tasks according to resource availability, deployment constraints and task relationships. Any resource or capability has an availability calendar, in-use costing, required preparations, required staffing, etc. Guitouni et al. [15,16] proposed to model a COA planning as a multiple mode resource-constrained project-scheduling (RCPS) problem since, from a methodological point of view, planning and scheduling are not much different. Multi-objectives RCPS problem has a complex combinatorial aspect. The RCPS problem is a generalization of the job-shop problem. It is NP-Hard and can be solved by using a heuristic procedure [23].

Scheduling and resource allocation problems are ones of the most studied problems in combinatorial optimization theory. In this work, we propose a progressive resource allocation methodology to solve multi-objectives RCPS for a given task schedule. This methodology should address the following question: Given a set of limited resources/capabilities, what is the "best" allocation for a given task schedule according to several objectives? The "best" or potential efficient solutions should be determined considering a set of heterogeneous and conflicting criteria (objectives).

Most studies reported in the literature have focused on the scheduling rather than on the resource allocation optimization. Moreover, in most cases, an aggregative approach is used to reduce the multi-objectives problem to a single objective optimization problem. The aggregation, despite its simplicity and its efficiency from a computational point of view, presents a serious difficulty when the objectives are non-commensurable or simply heterogeneous. Normalization of the objective functions is then unavoidable; all the objectives are transformed to the same scale. This transformation is sometimes the source of errors and dif-