Multi-objective Evolutionary Algorithms for Resource Allocation Problems

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Abstract. The inadequacy of classical methods to handle *resource allocation problems* (RAPs) draw the attention of evolutionary algorithms (EAs) to these problems. The potentialities of EAs are exploited in the present work for handling two such RAPs of quite different natures, namely (1) university class timetabling problem and (2) land-use management problem. In many cases, these problems are over-simplified by ignoring many important aspects, such as different types of constraints and multiple objective functions. In the present work, two EA-based multi-objective optimizers are developed for handling these two problems by considering various aspects that are common to most of their variants. Finally, the similarities between the problems, and also between their solution techniques, are analyzed through the application of the developed optimizers on two real problems.

1 Introduction

A *resource allocation problem* (RAP) involves the allotment of limited amount of resources to certain number of competitive events for achieving the most effective allotment of resources. It is a combinatorial optimization problem, and encountered in a variety of areas in operations research and management science, such as load distribution, production planning, computer scheduling, portfolio selection, apportionment, and so on. An RAP usually contains huge number of integer variables and constraints, a discrete search space, and multiple objectives, which make classical methods, such as linear and integer programming approaches, inadequate to handle RAPs. These inadequacy of classical methods draw the attention of non-classical techniques towards RAPs, among which evolutionary algorithms (EAs) are the widely preferred non-classical techniques. The potentialities of EAs are exploited in the present work for handling two such RAPs of quite different natures, namely (1) university class timetabling problem and (2) land-use management problem. The class timetabling problem involves the scheduling of classes[1], students, teachers and rooms at a fixed number of time-slots. Traditionally, the problem is solved manually by *trial and hit* method, where a valid solution is not guaranteed. Even if a valid solution

[1] A class is a meeting of a group of students and a teacher in a room for a lecture.

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is found, it is likely to miss far better solutions. These uncertainties motivate for the scientific study of the problem, and to develop an automated solution technique for it. Despite multiple criteria to be met simultaneously, the problem is generally tackled as a single-objective optimization problem. Moreover, most of the earlier works are concentrated on school timetabling, and only a few on university class timetabling. On the other hand, in many cases, the problem is over-simplified by skipping many complex class-structures, such as multi-slot, split, combined and group classes. Land-use management is another scheduling problem, where different competitive land uses, such as agriculture, forest or industries, are to be allocated to different units of a landscape to meet the desired objectives of land managers [29]. The problem has emerged today as a problem of great concern. Due to increasing human activities on land to meet various demands, land and its resources have been under tremendous pressure, which are causing significant transformations of land for a variety of land uses. Most of the land use changes occur without any logical planning to their long-term environmental impacts. Global warming, soil degradation, deforestation, loss of biodiversity, are all consequences of mismanagement of land and its resources. Thus, various land-use management practices are to be understood for developing an integrated land-use policy framework for improving soil quality, ensuing biomass production and food security, maintaining environmental stability, and extending socio-economic benefits [14]. These incommensurable objectives can be achieved only through optimization tools. Owing to the difficulty of deploying field experiments for direct assessment, it is important to enhance the knowledge by developing mechanistic models through extensive study. However, the problem is very new to the computational community, and only a little work has been done so far in this area. NSGA-II-UCTO and NSGA-II-LUM [8,9], two versions of EA-based multi-objective optimizer NSGA-II [11], are developed in the present work for optimizing university class timetabling problem and land-use management problem, respectively. NSGA-II-UCTO is applied for scheduling the classes of Indian Institute of Technology Kanpur, where much better solutions are obtained than a manually prepared solution which is in use. On the other hand, NSGA-II-LUM is applied to a Mediterranean landscape from Southern Portugal. However, due to non-availability of any existing solution for this landscape, the performance of NSGA-II-LUM could not be compared.

2 Related Works

The class timetabling problem drew the attention of the researchers starting with the study of Gotlieb [15], who formulated the problem by considering that each lecture contained one group of students, one teacher, and any number of time-slots which could be chosen freely. Since then the problem is being studied using different methods under different conditions. Initially it was mostly applied to schools. Since the problem in schools is relatively simple because of their simple class structures, classical methods, such as linear or integer programming approaches [19,30], could be used easily. However, the gradual consideration of