Path Relinking in Pareto Multi-objective Genetic Algorithms

Matthieu Basseur, Franck Seynhaeve, and El-Ghazali Talbi

Laboratoire d'Informatique Fondamentale de Lille (LIFL),
UMR CNRS 8022, University of Lille,
59655 Villeneuve d'Ascq Cedex, France
{basseur, seynhaev, talbi}@lifl.fr

Abstract. Path relinking algorithms have proved their efficiency in single objective optimization. Here we propose to adapt this concept to Pareto optimization. We combine this original approach to a genetic algorithm. By applying this hybrid approach to a bi-objective permutation flow-shop problem, we show the interest of this approach.

In this paper, we present first an Adaptive Genetic Algorithm dedicated to obtain a first well diversified approximation of the Pareto set. Then, we present an original hybridization with Path Relinking algorithm, in order to intensify the search between solutions obtained by the first approach. Results obtained are promising and show that cooperation between these optimization methods could be efficient for Pareto optimization.

1 Introduction

In solving Multi-objective Optimization Problems (MOPs), many methods scalarize the objective vector into a single objective. However, since several years, interest concerning MOPs using Pareto approaches always grows. Many of these studies use Evolutionary Algorithms (EAs) to solve MOPs [1, 2, 3].

The evolutionary approach called scatter search, and its generalized form called Path Relinking (PR), contrast with other evolutionary procedures, such as genetic algorithms, by providing unifying principles for joining solutions based on generalized path constructions. Joining solutions can be realized in both decisional and the objective spaces. Path relinking algorithms have recently been investigated in a number of studies for single-objective optimization, and especially in [4], where the Flow-shop problem is solved, in its single objective form.

In this paper, we propose a multi-objective approach to integrate Path relinking algorithms into EAs. We have to take into account several classical questions to implement a PR algorithm, and we propose some solutions for Pareto optimization. We have to define which distance operator has to be to used to join solutions. We propose a distance measure to compute distance in respect to an efficient neighborhood operator, the *Shift* operator. Then we define techniques to

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have an initial population (with EA), neighborhood generation to approach goal solutions from initial solutions, and path selection between solutions. Then, we propose to integrate path relinking into Pareto evolutionary algorithms to solve MOPs. We combine an Adaptive Genetic Algorithm (AGA) with Path relinking technique. In order to evaluate the effectiveness of this hybridization, we apply it to solve a Bi-Objective Flow-shop Scheduling Problem (BOFSP).

This paper is organized as follows. In section 2, we present the BOFSP. In section 3, we present a Pareto EA (AGA) developed to find an initial Pareto population. In section 4, we present cooperation between AGA and multi-objective Path relinking. Section 5 presents results on a large class of instances, which are non-exactly solved with exact approaches. In the last section, we discuss the effectiveness of this approach and perspectives of this work.

2 A Bi-objective Flow Shop Problem (BOFSP)

The Flow-shop Scheduling Problem (FSP) is one of the numerous scheduling problems. The FSP has been widely studied in the literature. Proposed methods for its resolution vary between exact methods such as the branch & bound algorithm [5], specific heuristics [6] and meta-heuristics [7]. However, the majority of works on flow-shop problem studies the problem in its single criterion form and aims mainly to minimize makespan, which is the total completion time. Some bi-objective approaches exist in the literature. Sayin et al. proposed a branch and bound strategy to solve the two-machine flow-shop scheduling problem, minimizing the makespan and the sum of completion times [5]. Sivrikaya-Serifoglu et al. proposed a comparison of branch & bound approaches for minimizing the makespan and a weighted combination of the average flowtime, applied to the two-machine flow-shop problem [8]. Rajendran proposed a specific heuristic to minimize the makespan and the total flowtime [6]. Nagar et al. proposed a survey of the existing multi-criteria approaches of scheduling problems [7].

FSP can be presented as a set of N jobs $J_1, J_2, \ldots, J_N$ to be scheduled on M machines. Machines are critical resources: one machine cannot be assigned to two jobs simultaneously. Each job J_i is composed of M consecutive tasks $t_{i1}, \ldots, t_{iM}$, where t_{ij} represents the j^{th} task of the job J_i requiring the machine m_j. To each task t_{ij} is associated a processing time p_{ij}. Each job J_i must be achieved before its due date d_i. In our study, we are interested in permutation FSP where jobs must be scheduled in the same order on all the machines.

In this work, we minimize two objectives: C_{max}, the makespan (total completion time), and T, the total tardiness. Each task t_{ij} being scheduled at the time s_{ij}, the two objectives can be computed as follows:

$$C_{max} = Max\{s_{iM} + p_{iM} | i \in [1 \ldots N]\}$$

$$T = \sum_{i=1}^{N} [max(0, s_{iM} + p_{iM} - d_i)]$$

In the Graham et al. notation [9], this problem is denoted: F/perm, $d_i/(C_{max}, T)$.