SOLVING THE FLOW SHOP SCHEDULING PROBLEM UNDER EVOLUTIONARY APPROACHES

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1. INTRODUCTION.

The flow shop scheduling problem (FSSP) [12], has held the attention of many researchers. In a simplest usual situation, a set of jobs must follow the same route to be executed on a set of machines (resources) and the main objective is to optimize some performance variable (makespan, tardiness, lateness, etc.). In the case of the makespan, it have been proved that when the number of machines is greater than or equal to three, the problem is NP-hard.

Evolutionary algorithms (EAs) have been successfully applied to solve flow-shop problems. Tsujimura et al [15] provided evidence of the performance of genetic algorithms (GAs) contrasted with conventional approaches using well known crossover operators such as *partially-mapped crossover* (PMX) [10], *order crossover* (OX) [10] and *cycle crossover* (CX), [11].

Because of the flow-shop problem is essentially a permutation schedule problem, a permutation can be used as the representation scheme of chromosomes, which is the natural one for a sequencing problem. The permutation representation, also called *order representation*, may lead to illegal offspring if the traditional one-point crossover operator is used. Reeves [13] proposed a hybrid approach, which inserts a chromosome as a seed in the initial population generated by the NEH heuristic algorithm. He suggested genetic operators in his implementation what he called *one-cut-point crossover* (OCPX). Reeves tested his GA on Taillard's benchmarks [14] and concluded that simulated annealing algorithms and GAs produce comparable results for the *flow-shop sequencing* problem for most sizes and types of problems, but GAs perform relatively better for large problems and reach a near-optimal solution more quickly.

Another way to face a problem involving permutations is by using *decoders* (Grefenstette [7]). Under this approach a chromosome gives instructions to a decoder on how to build a feasible solution. Even if decoders are mainly used in other constrained problems, we discuss a decoding scheme based on ordinal representation because it is easy to implement and produces feasible offspring under different conventional crossover methods making unnecessary the use of penalties or repair functions.

In EAs the common approach is to operate once on each mating pair after selection. Such procedure is known as the SCPC (Single Crossover Per Couple) approach. But in nature when the mating process is carried out, crossover is applied many times and the consequence is a multiple

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and variable number of offspring. *Multiple crossover per couple* (MCPC) [5,6] was applied to optimize classic testing functions and some harder (non-linear, non-separable) functions. For each mating pair MCPC allows a variable number of children. In those earlier works it was noticed that in some cases MCPC found better results than those provided by SCPC. Also a reduced running time resulted when the number of crossovers per couple increased, and best quality results were obtained allowing between 2 and 4 crossover per couple. Moreover, seeking for exploitation of a greater sample of the problem space, as an extension the multi-recombination can be applied to a set of more than two parents. In Eiben's *multiparent* (MP) approach [4], offspring creation is based on a larger sample from the search space and consequently larger diversity is supplied. This can help to avoid premature convergence. Eiben proposed, three scanning crossover (SX) methods; *uniform scanning crossover*, *occurrence based scanning* and *fitness based scanning* generating a single offspring. On different function optimization different versions of scanning crossover showed different behaviour. Following this idea and to improve performance, *multiple crossovers on multiple parents* (MCMP) [2,3], allows multiple recombination of multiple parents under *scanning crossover* (SX), expecting that exploitation and exploration of the problem space be adequately balanced .

Recently we implemented MCMP-STUD where a stud (breeding individual) is selected for recombining with a subset of parents from the old population. The members of this mating pool subsequently undergo multiple crossover operations. Setting of parameters n_1 (number of crossovers) and n_2 (number of parents) in a multirecombinated evolutionary algorithm remained as an open question in previous works; they were empirically determined. In *Deterministic Parameter Control* the parameter value is modified according with a deterministic rule, without any feedback of the searching process performed by the strategy. In the initial stages of the evolutionary process exploration is necessary while in the final stages exploitation of the relevant search space areas is advisable. Consequently, in the experiments, n_1 starts with a low value and then increases while n_2 starts with a high value and then decreases during the evolutionary process. The deterministic rule is a lineal function of the current generation number. Another researchers proposed *Adaptive Parameter control* and *Self adaptive Parameter Control.*[9] In the first case some feedback information of the searching process is used to determine the direction and magnitude of the change in the parameters, on the second case the parameters to be adapted are codified within the chromosome and undergo genetic operations so the best individuals of the population have better chances of survival and reproduction. Hence it is expected that better parameter values be more intensively propagated.

2. EXPERIMENTS AND RESULTS.

All the above cited approaches were tested on a selected sets of Taillard [14] instances for the flow shop scheduling problem. Given *n* jobs and *m* machines we run the experiments for the many instances of each of the following (*n* x *m*) problem sizes: 20x5, 20x10, 50x5, 50x10. For each instance a series of at least ten runs were performed. Besides, all the EAs used the following parameter settings: Population size: 100, Crossover Probability: 0.65, Mutation Probability: 0.01, Maximum No. of Generations: 100 and elitism was applied, mantaining through the evolution process the best individual found. As an indication of the performance of the algorithms the following relevant variables were chosen:

Ebest: It is the percentile error of the best found individual when compared with the benchmark upper bound for the optimal makespan. It gives us a measure of how far we are from the upper bound.

Epop: It is the percentile error of the final population mean fitness when compared with bencharmk upper bound for the optimal makespan. It tells us how far for the average indivual is from that upper bound makespan benchmark.

3. CONCLUSIONS.

The multi-recombinative approaches, MCPC and MCMP, applied to the Flow Shop Scheduling Problem were tested under different chromosome representation: permutations and decoders. All the evolutionary approaches were tested for many instances of selected FSSP problem sizes. All methods including multirecombination outperform SCPC regarding quality of results (best and average individuals) and speed to find near optimal solutions, in the case of permutation better results were obtained.

In the case of MCMP-STUD approach [16], one of the latest variant of the multi-recombinative family applied to the Flow Shop Scheduling Problem preliminary results are promising and showed its potential by providing new near-optimal solution for the whole set of instances selected for testing. In this approach the main objective is to improve quality of results including a significant set of schedules which their objective values are much closer to that corresponding to the best individual. This later feature also provides fault tolerance, because if eventually the dynamics of the system impedes using the best solution found then a better set of alternative solutions are available. Beside elitism, the presence of the stud ensures to retain good features of previous solutions. In the case of MCMP the open question about optimal (n_1, n_2) combination remains. We are implementing dynamic control and self adaptation of parameters, and investigating the effect of using alternative operators to test the method in larger benchmarks.

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