MULTIRECOMBINING RANDOM AND SEED IMMIGRANTS IN EVOLUTIONARY ALGORITHMS TO FACE THE FLOW SHOP SCHEDULING PROBLEM

Vilanova G. Villagra A., Pandolfi D., De San Pedro M,
Proyecto UNPA-29/B032[1]
Unidad Académica Caleta Olivia
Universidad Nacional de La Patagonia Austral
(9011) Caleta Olivia – Santa Cruz - Argentina
e-mail: gvilanov@satlink.com, {avillagra,dpandolfi,edesanpedro}@uaco.unpa.edu.ar
Phone/Fax : +54 297 4854888

Gallard R.
Laboratorio de Investigación y Desarrollo en Inteligencia Computacional (LIDIC)[2]
Departamento de Informática
Universidad Nacional de San Luis
Ejército de los Andes 950 - Local 106
(5700) - San Luis – Rep. Argentina
e-mail: rgallard@unsl.edu.ar
Phone: + 54 652 20823 Fax: +54 652 30224

ABSTRACT

In an *m*-machines *n*-jobs *flow-shop sequencing problem* each job consists of *m* operations and each operation requires a different machine, so *n* jobs have to be processed in the same sequence on *m* machines. The processing time of each job on each machine is given. Frequently, the main objective is to find the sequence of jobs minimizing the maximum flow time, which is called the *makespan*. The flow-shop problem has been proved to be NP-complete.
Evolutionary algorithms (EAs) have been successfully applied to solve scheduling problems. Improvements in evolutionary algorithms consider multirecombination, allowing multiple crossover operations on a pair of parents (MCPC, *multiple crossovers per couple*) or on a set of multiple parents (MCMP, *multiple crossovers on multiple parents).* MCMP-STUD and MCMP-SRI are novel MCMP variants, which considers the inclusion of a *stud-breeding individual* as a *seed* in a pool of random immigrant parents. Random immigrants provide genetic diversity while seed-immigrants afford the knowledge of some conventional robust heuristics. Members of the mating pool subsequently undergo multiple crossover operations.
Another question in a multirecombined EA is the setting of parameters n_1 (number of crossovers) and n_2 (number of parents). In the experiments conducted they were empirically determined, by a deterministic rule or by self adaptation of parameters n_1 and n_2. In the last case the idea is to code the parameters within the chromosome and undergo genetic operations. Hence it is expected that better parameter values be more intensively propagated.

KEYWORDS: Evolutionary algorithms, Multiple Crossovers, Multiple Parents, Flow Shop Scheduling Problem.

1. INTRODUCTION.

The flow-shop problem has been proved to be NP-complete [17]. Hence conventional and evolutionary heuristics have been developed by many researchers to solve the FSSP. Tsujimura et al [21] pro-

[1] The Research Group is supported by the Universidad Nacional de La Patagonia Austral.
[2] The LIDIC is supported by the Universidad Nacional de San Luis and the ANPCYT (National Agency to Promote Science and Technology).

vided evidence of the performance of (EAs) contrasted with conventional heuristics (CDS, Gupta, Palmer, etc.). [10,14,15].
By means of multirecombination (MCPC and MCMP), [6,7] better results were achieved. This implies higher quality of the best solution found throughout the evolutionary process, as well as an improved final population surrounding near optimal solutions. This later property also provides a sort of 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. The multirecombined methods were applied to FSSP and contrasted on a series of suitable experiments against previous successful approaches of Tsujimura and Reeves [1,21, 18].
Reeves proposed the idea of inserting seeds (good solutions) in evolutionary processes [18] as an alternative way to introduce problem-specific knowledge to the algorithm. In his approach Reeves, inserted one seed provided by a non evolutionary heuristic, only once in the initial population, expecting that its genetic material were occasionally exchanged by means of the selection mechanism.
Two novel MCMP variants were implemented, MCMP-STUD and MCMP-SRI [22,16], which considers the inclusion of a *stud-breeding individual* as a *seed* in a pool of random immigrant parents. In the case of MCMP-SRI, the stud (breeding individual) was generated by the CDS heuristics and the rest of the members of the parents pool are random immigrant. Random immigrants provide genetic diversity while the seed-immigrant afford the knowledge of some conventional robust heuristics. Members of the mating pool subsequently undergo multiple crossover operations.
In a multirecombined EA the setting of parameters n_1 (number of crossovers) and n_2 (number of parents) remained as an open question [5,8,9,11,19]. Two parameter control alternatives during the evolutionary processes were implemented: (DPC, *Deterministic Parameter Control*), the parameters are determined by applying a deterministic rule and (SPC Self Adaptation parameter Control) which advises to dynamically update parameters of the algorithm by evolving them as part of the chromosome structure [24].

In what follows we discuss these new multi-recombined methods, and show conclusions when they were applied to find the minimum makespan for selected instances of the FSSP. All approaches were tested for six Taillard´s benchmarks [20] for FSSP. We selected four instances for each of the following problem sizes: 20x5, 20x10, 20x20, 50x5, 50x10, and three instances for the 50x20 problem size. For each instance a series of ten runs were performed.

2. MULTIRECOMBINATION OF RANDOM AND SEED INMIGRANTS WITH THE STUD

Among other heuristics [13, 17], evolutionary algorithms have been successfully applied to solve scheduling problems [18, 21]. New trends in evolutionary algorithms make use of multiparent [3, 4] and multi-recombinative approaches [6, 7]. The later called, *multiple-crossovers-on-multiple-parents* (MCMP). Instead of applying crossover once on a pair of parents this feature applies n_1 crossover operation on a set of n_2 parents. Extreme exploitation can lead to premature convergence and intense exploration can make the search ineffective [12]. In order to improve the balance between exploration and exploitation in the search process was incorporated the use of a breeding individual (stud) which repeatedly mates individuals that randomly immigrates to a mating pool. The approaches are known as MCMP-STUD and MCMP-SRI respectively [22, 16, 24]. Under the last approach the random immigrants incorporate exploration (making unnecessary the use of mutation operations) and the multi-mating operation with the stud incorporates exploitation to the search process.
In MCMP-STUD [22, 23, 24], a mating pool is created by selection of n_2 individuals from the old population. Then the parent with minimum makespan (stud) mates every other parent in the pool. At that time *partially mapped crossover* (PMX) is applied to each couple and from the new offspring, after eventual mutation, the best one is selected for insertion in the next generation. The members of this mating pool subsequently undergo multiple crossover operations. The setting of of parameters n_1 (number of crossovers) and n_2 (number of parents) were determined during the processes evolution.

In MCMP-SRI [16,23,24], the process for creating offspring is performed as follows. From the old population an individual, assumed as the stud, is selected by means of proportional selection. The number of n_2 parents in the mating pool is completed with randomly created individuals (random immigrants). The stud mates every other parent, the couples undergo crossover and $2*n_2$ offspring are created. The best of these $2*n_2$ offspring is stored in a temporary children pool. The crossover operation is repeated n_1 times, for different cut points each time, until the children pool is completed. Finally, the best offspring created from n_2 parents and n_1 crossover is inserted in the new population. In MCMP-STUD and MCMP-SRI, following the Reeves´s idea [14,18] of inserting seeds (good solutions), the first individual in the population was generated in each generation as a *seed* by the non evolutionary heuristic CDS.

5. CONCLUSIONS.

The main objective of the MCMP-STUD recombinative method 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 at the end of the evolution. Beside elitism, the presence of the stud ensures to retain good features of previous solutions. Results obtained are promising and showed its potential by providing new near-optimal solution for the whole set of instances selected for testing in different one-machine problems.
In all cases MCMP-STUD and MCMP-SRI improve their performance, and much better in smaller problem size. MCMP-STUD and MCMP-SRI are methods, which inherently balance exploration and exploitation in the searching space when parameters are adequately selected, and consequenly when self adaptation is applied better results were obtained.

These results are promising and encourage us to deep forward investigation in MCMP-SRI approach, by incorporating more than one *seed* to the mating pool generated by different non evolutionary heuristics.

6. ACKNOWLEDGEMENTS

We acknowledge the cooperation of the project group for providing new ideas and constructive criticisms. Also to the Universidad Nacional de San Luis, the Universidad Nacional de La Patagonia Austral, and the ANPCYT from which we receive continuous support.

7. REFERENCES

[1] Bain M., Ferreyra J., Pires A., Varas V., Vilanova G., Gallard R.H, ¨Enhanced Evolutionary Approaches To The Flow Shop Scheduling Problem¨, Second Interna-tional ICSC Symposium of Intelligent Systems EIS 2000, June 27-30 , 2000, University of Paisley, Scotland U.K.

[2] Campbell H., Dudek R., Smith M., *A heuristic algorithm for the n job m machine sequencing problem*, Management Science 16,1970, 630-637.

[3] Eiben A.E., Raué P-E., and Ruttkay Zs., *Genetic algorithms with multi-parent recombination*. In Davidor, H.-P. Schwefel, and R. Männer, editors, Proceedings of the 3rd Conference on Parallel Problem Solving from Nature, number 866 in LNCS, pages 78-87. Springer-Verlag, 1994

[4] Eiben A.E, van Kemenade C.H.M.,and Kok J.N., *Orgy in the computer: Multi-parent reproduction in genetic algorithms*. In F. Moran, A Moreno, J.J Merelo, and P. Chacon, editors. Proceedings of the 3rd European Conference on Artificial Life, number 929 in LNAI, pages 934-945. Springer-Verlag, 1995.

[5] Eiben A. E., Hinterding R.,Michalewicz Z. – *Parameter Control in Evolutionary Algorithms*, IEEE Transactions on Evolutionary Computation, Vol. 3 No.2, 1.999.

[6] Esquivel S., Leiva A., Gallard R., - *Multiple Crossover per Couple in Genetic Algorithms*, Proceedings of the Fourth IEEE Conference on Evolutionary Computation (ICEC'97), pp 103-106, ISBN 0-7803-3949-5, Indianapolis, USA, April 1997.

[7] Esquivel S., Leiva H.,.Gallard R., *Multiple crossovers between multiple parents to improve search in evolutionary algorithms*, Proceedings of the 1999 Congress on Evolutionary Computation (IEEE). Washington DC, pp 1589-1594.

[8] Esquivel S., Leiva H.,.Gallard R., *Self-Adaptation of Parameters for MCPC in Genetic Algorithms*, Proceedings of the 4th Congreso Argentino de Ciencias de la Computación (CACiC'98), pp 419-425. Universidad Nacional del Comahue, Argentina, Octubre 1998.

[9] Grefenstette J.J., *Optimization of control parameters for genetic Algorithms*, IEEE Transactions on Systems, Many and Cybernetics, 16 (1):122-128 1988.

[10] Gupta J., *A functional heuristic algorithm for the flowshop scheduling problem*, Operational Research Quarterly 22, 1971,39-48.

[11] Hinterding R., Michalewicz Z., Eiben A. E. – *Adaptation in Evolutionary Computation – A survey,* Proceedings of the 4th IEEE International Conference on Evolutionary Computation, Indianapolis, April 13-16, 1.997, pp. 65-69.

[12] Michalewicz, M., *Genetic Algorithms + Data Structures = Evolution Programs*. Springer, third revised edition, 1996.

[13] Morton T., Pentico D*., Heuristic scheduling systems,* Wiley series in Engineering and technology management. John Wiley and Sons, INC, 1993.

[14] Nawaz M., Enscore E., Ham I., *A heuristic algorithm for the m-machine n-job flow shop sequencing problem*. Omega vol II, pp 11-95, 1983.

[15] Palmer D., *Sequencing jobs through a multistage process in the minimum total time*- A quick method of obtaining a near optimum, Operational Research Quarterly 16, 101-107, 1965.

[16] Pandolfi D., Vilanova G., De San Pedro M., Villagra A., Gallard R. *Solving the single-machine common due date problem via studs and inmigrants in evolutionary algorithms*. Proceedings of the SCI 2001. World Multiconference on Systemics, Cybernetics and Informatics. Orlando. USA, June 2001.

[17] Pinedo Michael (1995) – *Scheduling- Theory , Algorithms, and Systems*. Prentice Hall International in Industrial and System Engineering.

[18] Reeves C., *A genetic algorithm for flow shop sequencing*, Computers and Operations Research, vol 22, pp5-13, 1995.

[19] William M. Spears*: Adapting Crossover in Evolutionary Algorithms*. Proceedings of the Evolutionary Programming Conference, 1995.

[20] Taillard, E. *Benchmarks for basic scheduling problems*, European Journal of Operational Research, vol.64,pp.278-285,1993. http://www.idsia.ch/~eric/problems.dir/ordonnancement.dir/ordonnancement.html).

[21] Tsujimura Y., Gen M., Kubota E., *Flow shop scheduling with fuzzy processing time using genetic algorithms.* The 11^{th} Fuzzy Systems Symposium pp 248-252. Okinawa. 1995.

[22] Vilanova G., Pandolfi D., De San Pedro M., Villagra A., Gallard R. Multiple recombination and breeding in evolutionary algorithm for flow shop scheduling problems. Proceedings of the International Conference in Soft Computing. University of Paisley, Scotland, U.K., June2001.

[23] Vilanova G., Pandolfi D., De San Pedro M., Villagra A., Bain M, Gallard R. *Deterministic Parameter Control in Multirecombinated Evolutionary Algorithms for the Flow Shop Scheduling Problem*. Proceedings of the SCI, World Multiconference on Systemics, Cybernetics and Informatics - 2001 Orlando. USA. June 2001

[24] Vilanova G., Pandolfi D., De San Pedro M., Villagra A., Bain M, Gallard R. *Parameter Control in Multirecombinated Evolutionary Algorithms for the Flow Shop Scheduling Problem*. Proceedings of the 7^{th} Argentine Congress of Computer Sciences - 2001 El Calafate . Argentina.