FACING THE JOB SHOP SCHEDULING PROBLEM WIH HYBRID EVOLUTIONARY ALGORITHMS

Salto Carolina, Fernández Natalia, Alfonso Hugo
Proyecto UNLPAM-09/F015[1]
Departamento de Informática - Facultad de Ingeniería
Universidad Nacional de La Pampa
Calle 110 esq. 9
(6360) General Pico – La Pampa – Rep. Argentina
e-mail: {saltoc, fernaty, alfonsoh }@ing.unlpam.edu.ar
Phone: +54 (2302) 422780/422372, Ext. 6302

Gallard Raúl
Proyecto UNSL-338403[2]
Departamento de Informática
Universidad Nacional de San Luis
Ejército de los Andes 950 - Local 106
(5700) - San Luis -Argentina
e-mail: rgallard@unsl.edu.ar
Phone: +54 (2652) 420823
Fax : +54 (2652) 430224

SUMMARY

Evolutionary algorithms (EAs) offer a robust approach to problem solving. EAs are extremely flexible and can be extended by incorporating alternative approaches to favour he search process. One way is to hybridize an evolutionary algorithm with standard local search procedures [10,11], such as hill climbing [12], simulated annealing [15] and tabu search [4]. Individual solutions can be improved using local techniques and then placed back in competition with other members of the population. The hybrid approach complements the properties of evolutionary algorithm and local search heuristic methods. An evolutionary algorithm is used to perform global search to escape from local optima, while local search is used to conduct fine-tuning.

This line of investigation is oriented to incorporate local search techniques at different stages of an evolutionary algorithm to solve the Job Shop Scheduling Problem (JSSP).

Hybridizing conventional heuristics into evolutionary algorithms can be done in a variety of ways, including the following [2,12]:

- ✓ Incorporate heuristics into initialization to generate a well-adapted initial population. In this way, a hybrid evolutionary algorithm with elitism can guarantee to do no worse than the conventional heuristic does.
- ✓ Incorporate a local search heuristic as an add-on to the basic loop of the genetic algorithm, working together with mutation and crossover operators, to perform quick and localized optimization in order to improve offspring before returning it to be evaluated.
- ✓ Improve the final population with a local search heuristic.

With the hybrid approach, evolutionary algorithms are used to perform global exploration among population while other heuristic methods are used to perform local exploitation around chromosomes. Due to the complementary properties of evolutionary algorithms and conventional heuristics, the hybrid approach often outperforms either method operating alone. When designing a hybrid genetic algorithm, a fundamental principle is to hybridize where possible.

Among simulated annealing, tabu search, hill climbing, and other heuristics, SA was the first local search algorithm chosen to use. SA is incorporated at different stages of the evolutionary process:

---

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

either when the initial population is created, or in intermediate stages, or in the final population, or within the evolutionary process itself. Consequently, the alternatives for hybridization considered were:

- ✓ HEA1: SA is applied to some percentage X% of the best (or worst) individuals in the randomly generated initial population, to establish a better starting point for the evolutionary process.
- ✓ HEA2: SA is applied to some percentage X% of the best (or worst) individuals in an intermediate population. In this option the evolutionary process is suspended after certain number α of generations, then local search is applied and when it finishes the evolutionary process is restarted for the subsequent α generations.
- ✓ HEA3: SA is applied to all individuals in the final population.
- ✓ HEA4: As it is usual with genetic operators, here SA is applied with certain probability to each new generated individual.

In previous works [13, 1, 14, 9] diverse representations were contrasted. Operation based representation (OBR) was the one with best results, although for those more complex instances suboptimal solutions were far from the known optimum. OBR encodes a schedule as a sequence of operations, and each gene stands for one operation. Gen, Tsujimura and Kubota proposed to identify all operations for a job with the same symbol and then interpret them according to the order of occurrence in the sequence for a given chromosome [3, 7]. For an n-job m-machine problem a chromosome contains n x m genes. Each job appears in the chromosome exactly m times, and each repeated gene does not indicate a concrete operation of a job but refers to an operation which is context-dependent. It is easy to see that any permutation of the chromosome always yields to a feasible schedule. In order that chromosomes represent feasible schedules a specially designed crossover operator called *partial schedule exchange* [6] was used. For mutation a simple *exchange mutation* operator was adopted.

For simulated annealing the initial temperature was set to 1000 and the algorithm stops after 500 iterations. For operation-based representation, the neighbourhood for a given chromosome was considered as the set of chromosomes (schedules) attainable from a given chromosome by exchanging the positions of λ genes (randomly selected and non-identical genes). In our experiments, λ was fixed at 2.

CONCLUSIONS AND FUTURE WORK

The hybrid EA is contrasted against a conventional EA both using OBR on the set of those instances that resulted more difficult in previous works. When contrasted against a similar conventional evolutionary approach all of them show a better performance in the quality of solutions provided.

The testing set [8] was chosen as a difficult one (*ft10, ft20, abz6* and *abz7* instances) and the improvements on results are significant. In *abz6* instance, the optimum value was reached when fine-tuning is periodically applied during the evolutionary process. Also high quality results are obtained when fine-tuning is applied with certain probability to each generated individual.

These preliminary experiments used fixed parameter settings and obtained promising results. Consequently, to improve these results, future work will include dynamic control of parameters depending on the progress of the search process.

The effectiveness of simulated annealing depends on the design of the neighbourhood. One of the most important elements in local search is to determine the neighbourhood for a given schedule. In previous works, a simple way to generate a neighbour has been considered, but a possible extension is to examine another ways to build that neighbourhood.

Another line of investigation in course related with SA is to use different ways to reduce the temperature. One of them consists in decrementing the current temperature at a fix percentage meanwhile the other trials to do a lineal reduction. The former presents big reductions at the first iterations of SA algorithm and became to be smaller towards the end of the runs. Making a lineal reduction produce equal temperature reductions during the run.

Moreover, inclusion of another techniques like tabu search and hill climbing is considered. But presently only the hybrid EA approaches that give the best results are tested.

REFERENCES

[1] Alfonso, H., Salto, C., and Gallard, R., Análisis Comparativo de la Aplicación de Distintos Operadores Genéticos al Problema de Job Shop Scheduling, in *Anales del Workshop de Investigadores de Ciencias de la Computación*, WICC 2000, Universidad Nacional de La Plata, 2000.

[2] Davis, L., editor, *Handbook of Genetic Algorithms*, Van Nostrand Reinhold, New York, 1991.

[3] De Jong, K., *Genetic algorithms: a 25 Years Perspective, in Computational Intelligence: Imitating Life*, IEEE Press, New York, pag. 125-134, 1994.

[4] Dell'Amico, M., y Trubian, M., Applying Tabu Search to the Job-Shop Scheduling Problem, en *Annals of Operations Research*, vol. 40, pag. 231-252, 1993.

[5] Gen, M. and Cheng, R., *Genetic Algorithms and Engineering Design*, Wiley-Interscience Publication John Wiley & Sons, Inc, 1997.

[6] Gen, M., Tsujimura, Y., and Kubota, E., Solving Job-Shop Scheduling Problem Using Genetic Algorithms, in Gen, M., y Kobayashi, T. (editores), *Proceedings of the 16th International Conference on Computers and Industrial Engineering*, Ashikaga, Japan, pag. 576-579, 1994.

[7] Kubota, A., Study on Optimal Scheduling for Manufacturing System by Genetic Algorithms, Master Thesis, Ashikaga Institute of Technology, Ashikaga, Japan, 1995.

[8] Lawrence S., *Resource constrained project scheduling: an experimental investigation of heuristic scheduling techniques,* (Supplement),Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh, Pennsylvania, 1984.

[9] Minetti, G., Salto, C., Alfonso, H. and Gallard, R., A comparison of Two Multirecombinated Evolutionary Algorithms for the Hob Shop Scheduling Problem, in *Proceedings del VI Congreso Argentino de Ciencias de la Computación*, CACIC 2000, Universidad Nacional de la Patagonia San Juan Bosco, 2000.

[10] Morton, T.E. and Pentico, D., *Heuristic Scheduling Systems*, Wiley, New York, 1993.

[11] Pinedo, M, *Scheduling: Theory, Algorithms and Systems*, Prentice Hall, 1995.

[12] Renders, J. and Bersini, H., Hybridizing Genetic Algorithms with Hill-Climbing Methods for Global Optimization: Two Possible Ways, in Fogel, D., (editor), *Proceedings of the first IEEE Conference on Evolutionary Computation*, IEEE Press, Orlando, FL. 1994.

[13] Salto, C., Alfonso, H., and Gallard, R., Multiplicity and Incest Prevention in Evolutionary Algorithms to Deal with de Job Shop Problem, in *Proceedings of the Second ICSC Symposium on Engineering of Intelligent Systems*, University of Paisley, Scotland, pag, 451-457, 2000.

[14] Salto, C., Minetti, G., Alfonso, H. and Gallard, R., A Hybrid Evolutionary Algorithm: Multirecombination with Priority Rule Based Representation for the Job Shop Scheduling Problem, in *Proceedings del VI Congreso Argentino de Ciencias de la Computación*, CACIC 2000, Universidad Nacional de la Patagonia San Juan Bosco, 2000.

[15] Van Laarhoven, P., Aarts, E., y Lenstra, J., Job Shop Scheduling by Simulated Annealing, en *Operations Research*, vol. 40, nro. 1, pag. 113-125, 1992.