Software Implementation and Experimentation with a New Genetic Algorithm for Layout Design

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Abstract

This paper discusses the development of a new GA for layout design. The GA was already designed and reported. However the implementation used in the earlier work was rudimentary and cumbersome, having no suitable Graphical User Interface, GUI. This paper discusses the intricacies of the algorithm and the GA operators used in previous work. It also reports on implementation of a new GA operator which was not included in earlier reports. The software was then used to conduct a series of experimentations to establish the best configuration of the operators for better results. The paper is also demonstrating a comparison of the new GA results and results from the literature. In addition the results show the solution of two new problems by various methods from the author's own layout developments in industry. The results demonstrate that in most cases the new GA is superior to the existing methods. In particular the speed of the new GA is achieving a reasonable solution is significantly low.

1. Introduction

The material handling cost (MHC) can be reduced by 10–30% by robust facilities layout and material handling systems (Tompkins, 1996). Better design of layouts has become a research issue leading to many approaches. The quadratic assignment problem (QAP) is a famous layout model, which assigns n equal area departments to n equal sized locations. However, in general QAP is an NP-complete problem (Gorey, 1979). To deal with mo general unequal locations, several sub-optimal approaches to solve facilities layout problems using heuristics have also been developed such as simulated annealing, tabu search, artificial neural networks, and genetic algorithms (GAs) widely implemented to solve combinatorial optimization problems (Gero, 1997) and are considered to be robust approaches in artificial intelligence. Facilities layout is interconnected to running costs in the manufacturing industry.

An effective layout should arrange and integrate physical facilities to utilize the offering resource leading to multiple objectives including minimizing investment in equipment, minimizing overall production time, utilizing existing space the most effectively, employee convenience, safety and comfort, flexibility for arrangement and operation, and minimizing material handling cost (Francis, 1992). Most of the facility layout problems found in the literature deals with the arrangement of rectangular departments. There are applications, however, in which an orthogonal arrangement of departments is not necessarily a requirement. For an interesting survey the reader is referred to (Kusiak, 1987). The problem of determining the optimal location of areas in a plant falls in the class of the Quadratic Set Covering (QSC) problems. Because of the large amount of possible area shapes and locations in a plant, there are no computationally feasible optimal or hybrid algorithms available for the QSC problem (Zhang, 1999).

Genetic algorithms are a family of parallel, randomized-search optimization heuristics which are based on the biological process of natural selection (Holland, 1975). In 1992, Tam (1992) published a work in the European Journal of operational Research on how to use Genetic Algorithms to solve plant layout problems. Afterwards, in 1995, Tate and Smith (1995) published a report on the application of Genetic Optimization to plant layout problems, which focused on the case of compartmenting problems within different surfaces. Suresh, Vinod and Sahu (1995) presented a further application of Genetic Algorithms to the field of layout. Wang et al. (1996) produced software based on GA for layout design. Tam and Chan (1998) further improved the GA based results using the Gambler's ruin method, to make sure that the chromosome represents a slicing tree.

The work carried out by Chittllappilly (2003), implemented a new chromosome representation and decoding scheme introduced by Hanafi (2000) based on slicing trees, using a two dimensional chromosome. It produces better results than existing representations mainly due to the fact that the new chromosome generated by GA operators are always feasible, thus no need for feasibility checks. Accordingly the new algorithm requires considerably less computational effort to produce results for practical sized problems. Further work and experiments were reported by Shayan (2004) to test the performance of the new algorithm under varying parameter settings and problem sizes, as compared with other algorithms from the literature. The experiments were conducted with rudimentary software.

This paper is reporting on yet further extension of the previous work in which a unified user friendly interface called Genetic Algorithm for Layout Planning (GALP) was developed to facilitate further experimentation with the above mentioned GA algorithm. In addition it implemented an additional new operator devised by Shayan (1999) to the GA and tested the effect of this operator on the solution space exploration.

2. GA Representation and Operators

We invite the readers to consult the pervious papers for details of the chromosome design, to avoid repetition. Here the minimum background necessary to understand the content of the software is introduced briefly.

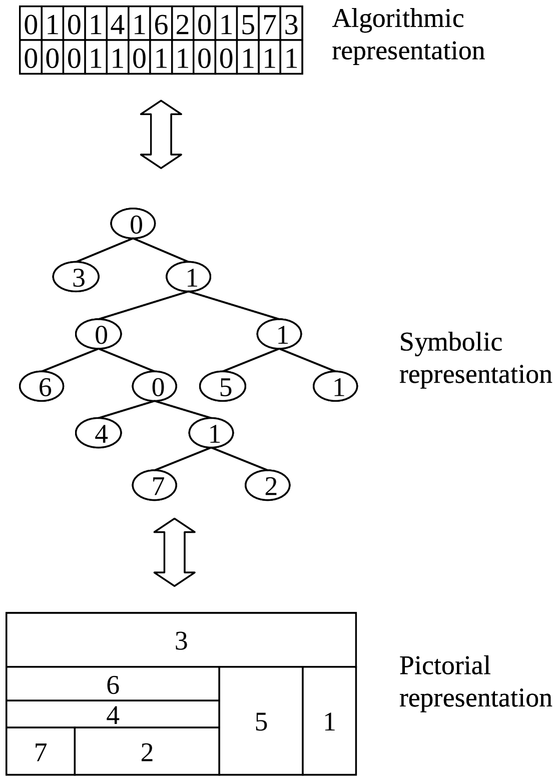


Figure 1. The chromosome structure and the corresponding the search tree and layout

GA Operators:

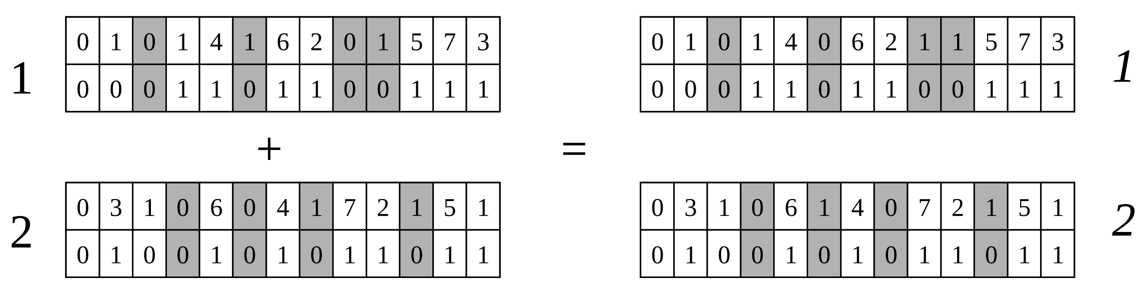


Figure 2– Single point crossover

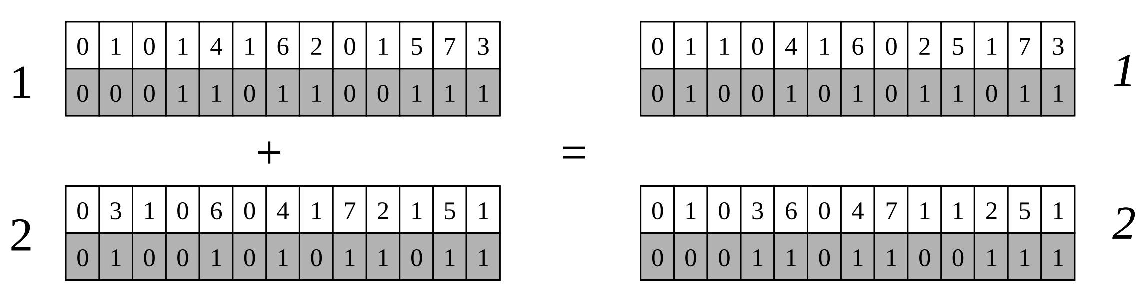


Figure 3 – Row 2 exchange crossover

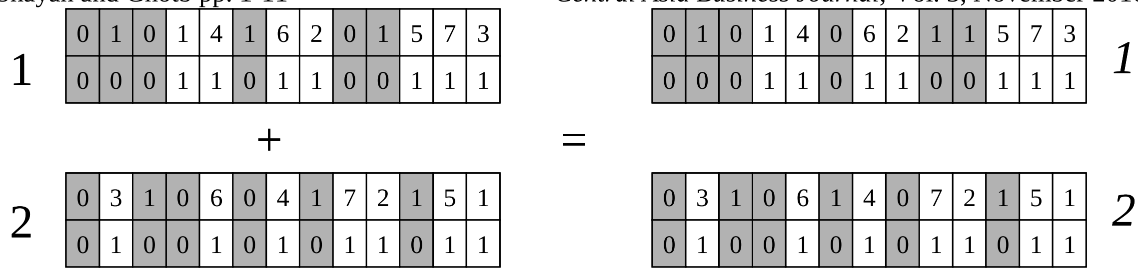


Figure 4 – Internal exchange crossover

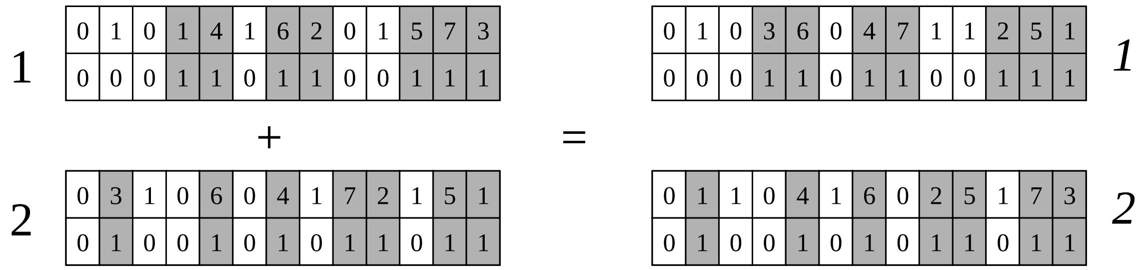


Figure 5 – External exchange crossover

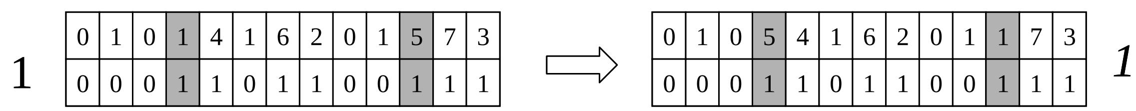


Figure 6 – Mutation

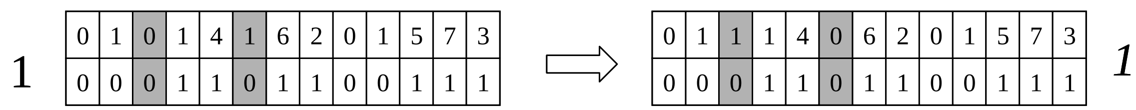


Figure 7 – Mutate-alter

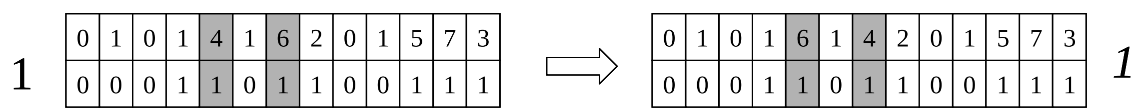


Figure 8 – Mutate-exchange

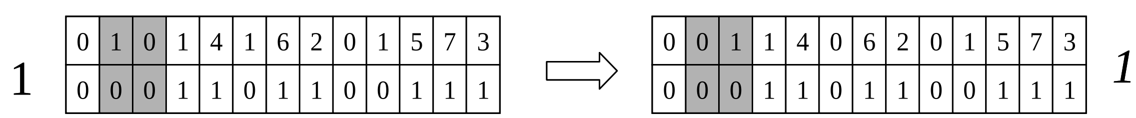


Figure 9 – Mutate-swap

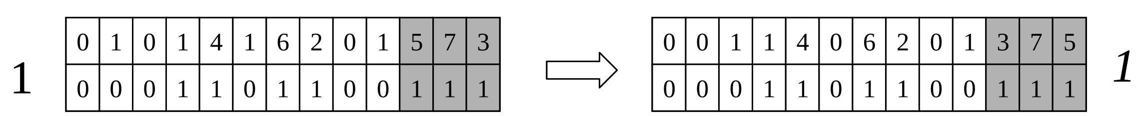


Figure 10 – Mutate-invert

2.1 Cloning Operation

Consider the layout and its chromosome representation of Fig 11. The two type of cloning are shown in Figures 12 and 13.

0	3	1	0	1	6	0	5	1	4	1	7	2
0	1	0	0	0	1	0	1	1	1	0	1	1

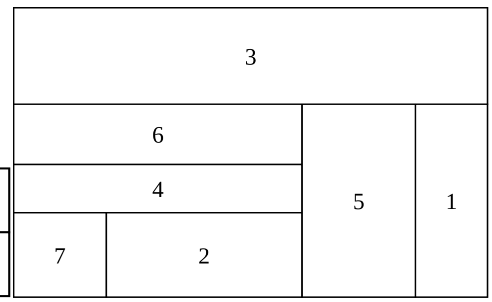


Fig 11 – A Chromosome representation of a layout

0	1	3	0	1	0	6	5	1	1	4	7	2
0	0	1	0	0	0	1	1	1	0	1	1	1

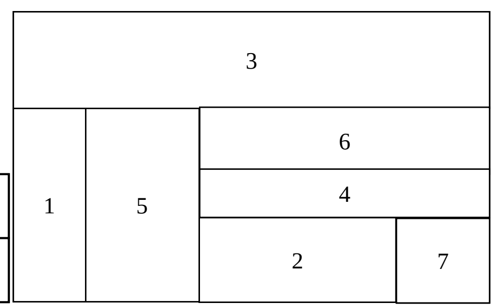


Figure 12 Chromosome representation and layout after horizontal cloning

0	3	1	1	0	1	5	6	0	4	1	2	7
0	1	0	0	0	1	1	1	0	1	0	1	1

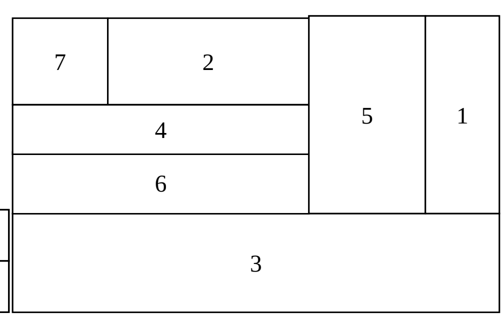


Figure 13 Chromosome representation and layout after vertical cloning

3. Implementation

The software is introduced as in Figure 14.

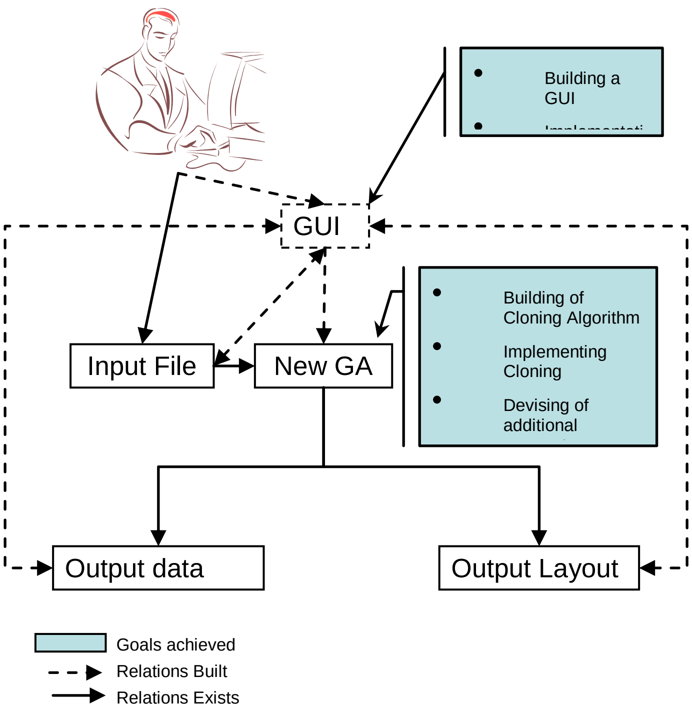
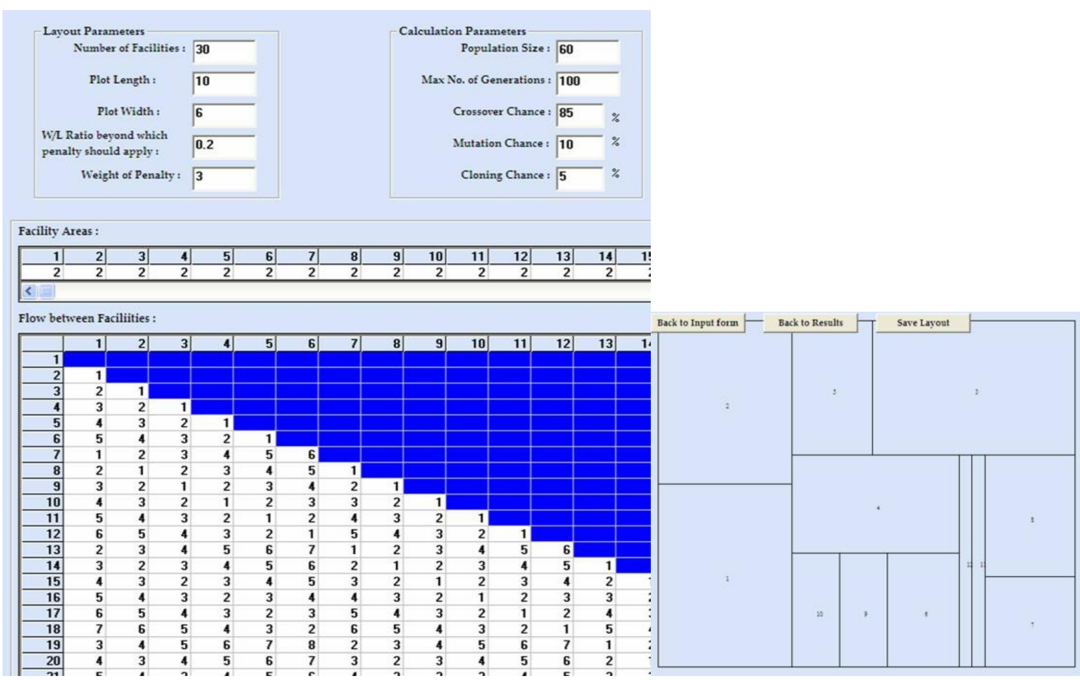


Figure 14 The overall structure of the software

We demonstrate only a few of the GUI features in a collectively referred to Figure 15



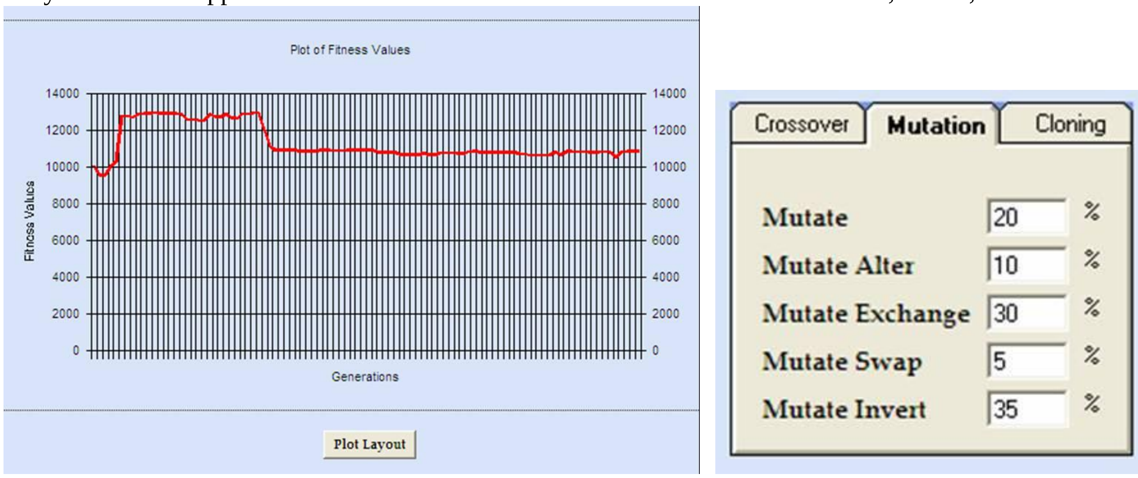


Figure 15 Examples of the Guis developed

4. Experimentations

The test problems can from the literature include Bazaraa (1979), Moghaddam (1997), Imam and Mir (1993), QAPLIB, (www.opt.math.tu-graz.ac.at/qaplib/), J E Beasly (http://mscmga.ms.ic.ac.uk/jeb/or/faclay.html). These consist of unequal area problems with 11, 12, 14 and 20 facilities and equal area problems with 30, 40, 50, 60, 80 and 100 facilities. The real life problems were from two local companies. The results from the New GA are tabulated against the results from other sources

Table 1 – The values of parameters used for all the experiments

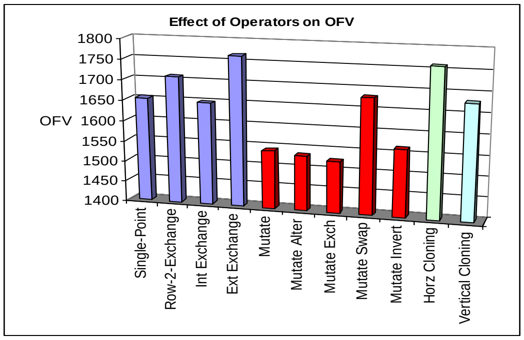
Population size	No. of generations	Crossover rate	Mutation rate	Cloning rate	Weight of penalty	length/width ratio
60	60	80	10	10	3	0.33

Table 2 – The summary of results of experiments carried on different problems

Problem	Sources of solution	OFV obtained
11 Facility	GALP	12249
	New GA	16769
	J E Beasly	10189
12 Facility	GALP	11238
	New GA	**10729**
	Bazaraa (1975)	28158
	Moghaddam (1997)	25738
14 Facility	GALP	6772
	New GA	**6214**
	Bazaraa (1975)	16341

	Moghaddam (1997)	14407
20 Facility	GALP	1444
	New GA	1547
	Bazaraa (1975)	2529
	Moghaddam (1997)	2509
30 Facility	GALP	8020
	New GA	7682
	QAPLIB	6214
40 Facility	GALP	191595
	New GA	221104
	QAPLIB	2492850
50 Facility	GALP	410509
	New GA	**395852**
	QAPLIB	3854359
60 Facility	GALP	624845
	New GA	**616930**
	QAPLIB	5555095
80 Facility	GALP	1355758
	New GA	1547083
	QAPLIB	10329674
100 Facility	GALP	2714412
	New GA	**2265172**
	QAPLIB	15824355
Topform	GALP	1084521
	New GA	1534396
	3 OPT	1435419
	Simulated Annealing	1181748
	Mosel	1413604
	Cellular Manufacturing	1308422
Moran	GALP	7030
	New GA	**7381**

The graph shown below is the best OFV generated for a 20 facility problem when only one kind of operator was used. The performances are as plotted in Figure 16.



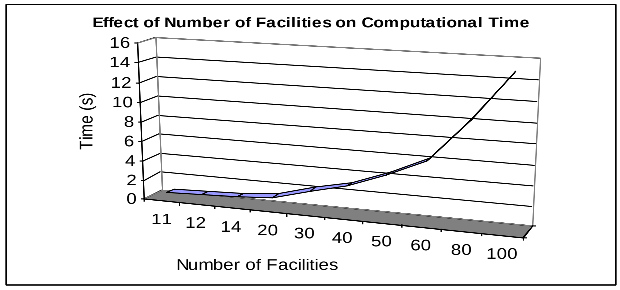


Figure 16 – Examples of experiments: Effect of operator types and number of facilities

5. Conclusions

This paper demonstrates the result of a software development exercise in a relatively difficult area. As a result we were able to conduct several experimentations on a GA algorithm for layout design. This included change of all the parameters and measurement of the fitness of the solutions. Everything is conducted interactively and the user can observe the solution as it develops. The results demonstrate the user-friendliness of the software in producing very interesting results for the algorithm's robustness and speed. Note that even for 100 facilities, the time is in seconds while other software is incapable of reaching a solution in reasonable time. We acknowledge that the experimentation is still limited and more work needs to be done to also improve the software.

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