An ILP-GA Based Approach for Nesting Scheduling in Carpet Weaving Industries

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Abstract: In many industrial cases, the nesting problem and the production scheduling should be addressed at the same time. The complexity of the combined problems often decreases both nesting efficiency and overall production. In textile industries, this problem is faced in carpet weaving mills.
The present work introduces an optimization method related to the carpet weaving industry using the integer linear programming and genetic algorithm (ILP-GA) combined method. The developed method is to layout simultaneous orders of carpets with predefined widths, lengths and ordered amounts for electronic jacquard looms with fixed widths. The results show that the improvement in the production efficiency of a carpet weaving mill is satisfied.

Introduction

In carpet industry, carpets with specified widths, lengths and designs are woven on make-to-order basis according to customer desire. Planners assign sets of carpet orders to different looms considering their compatibilities, due dates, customers and suitabilities to looms width. Carpets with same yarn type, knot density and same (or similar) color set are compatible to be produced in on a single loom.
In carpet nesting problem the term ‘‘path’’ is used for an uninterrupted stream of carpets produced on a single loom (with a fix width) in one setup and is handled as a whole. A path typically consists of compatible carpets with varying lengths and widths. On the other hand, a ‘‘schedule’’ includes several paths and it describes the production plan of one outstanding order. The composition of carpets in paths is transferred into the computer which controls looms electronically. Regarding these definitions [1], a path comprises the smallest production unit whereas a schedule is the smallest planning unit.
Carpets assigned to a path on a single loom span the loom width and the path length as much as possible, but there are normally empty (scrap) areas generated in the path.
Amani et al. [2] employed genetic algorithm method for carpet loading program. The problem with a single loom width was studied by Demir et al. [1]. The NP-completeness of the problem, generalized the work [3].
The present work introduces a novel method using the combination of linear programming and genetic algorithm (ILP-GA) to find a reasonable schedule for any customer order.

Problem description

To understand the problem a customer order should be initially considered. A customer order contains |C| different carpets with (w_c, l_c, n_c), c ∈ C, where (w_c, l_c) are the width and length of carpet type c and n_c is the ordered amount. In Table 1 an order sample is illustrated assuming all carpets can be produced on a single loom.

Table 1- A sample of customer order

Carpet (c)	Design	Width (w_c) *mm*	Length (l_c) *mm*	Amount (n_c)
c_1		175	200	18
c_2		175	225	16
c_3		50	80	30
c_4		150	100	20

There is usually an tolerance (T) in the amount ($n_c(1\pm T)$) which is acceptable by customer.

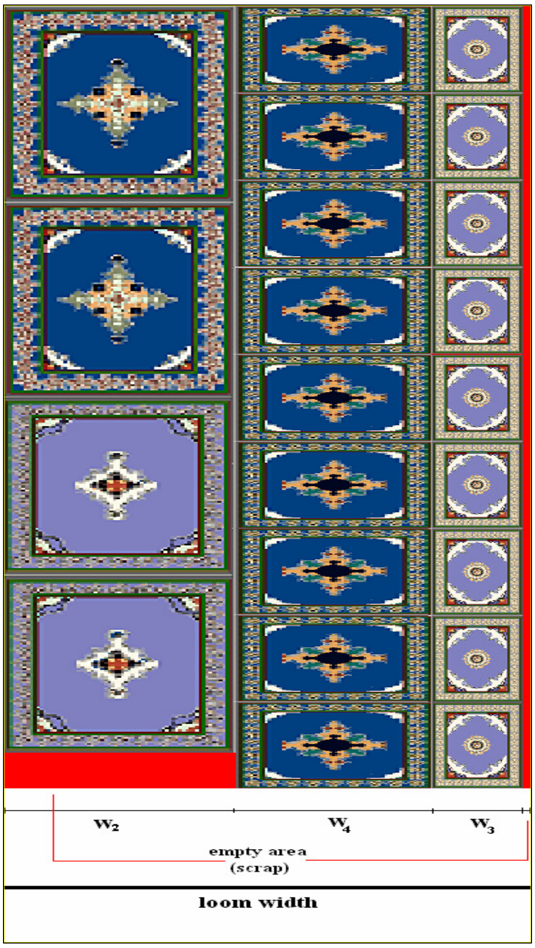

Figure 1- A path sample with four different types of carpets and empty area

Assigning carpets to looms widthwise in a path is the classical trim loss problem. On the other hand, two or more carpets with different lengths can be woven in one continuous path, provided that they have same width. Carpets assigned to a path on a single loom span the loom width and the path length as much as possible, but usually there are empty areas (scrap) generated in the path. Naturally, the main object is to minimize these empty areas. Figure 1 illustrates a path sample with five different carpet types labeled from c_1 to c_4. It should be noted that carpets c_1 and c_2 have same width and therefore can be scheduled in the same strip. In this illustration, the scrap is the red area between carpets and paths.

Although there are many details in carpet production, we will only focus on the problem of assigning a given set of compatible carpets to paths so as to minimize the total scrap and the number of paths (setups) in a schedule.

Let there be K different types of loom while W_k is the width of loom type k.

There is a limit (S_{max}) for the maximum number of strips assigned to a loom since the number of knife settings is limited. After weaving the path, it is transferred to the cutting station by means of carts. Therefore, a too heavy (too long) path becomes impossible to handle. To deal with this logistic problem, a length on the path, L_{path} is imposed. Since the weight depends on the density of the woven carpet, this limit is definable by the planner. In Table 2 a sample of carpet loom's specifications is shown.

Table 2- sample of carpet loom's specifications

Loom Type (k)	Number of Loom	Loom Wide (W_k) mm	loom Knife (S_{max})	Path Length (L_{path}) m
1	4	400	7	30±5
2	5	410	7	30±5

To schedule production orders the following issues should be considered:

- carpet loom's limitation,
- all looms should have same path length for weaving,
- carpets must be cut at full length,
- least empty areas in path is desired

Methodology

Integer programming formulation

The enumeration algorithm is initially used to generate the matrix (Q) which contains all acceptable width sets in path. The acceptable width set consists of the carpet types equal or less than the number of S_{max}+1and the sum of carpet's width is less than the loom width. The column of matrix Q is equal to S_{max}+1, the row of matrix Q is the same as acceptable width set and the repeated set is omitted. To decrease the size of Q the width loom loss limitation can be used in this step. A sample of Q is illustrated in Figure 2.

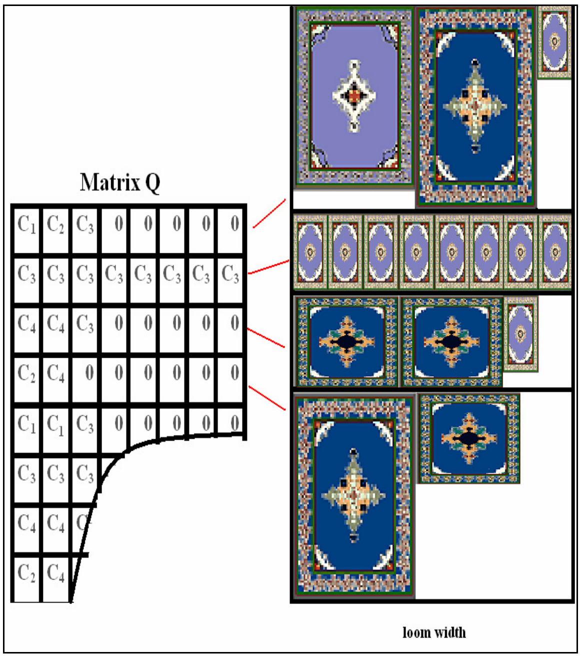

Figure 2- A sample of matrix Q

In next step, for decreasing the length loss in acceptable width set, the number of carpet types which should be used in each width set to prevent length loss is calculated. The result is registered in pattern matrix P. If the length of a pattern is larger than L_{path} or the number of carpets is more than customer order, the pattern should be omitted. The pattern matrix of sample Q is shown in Figure 3.

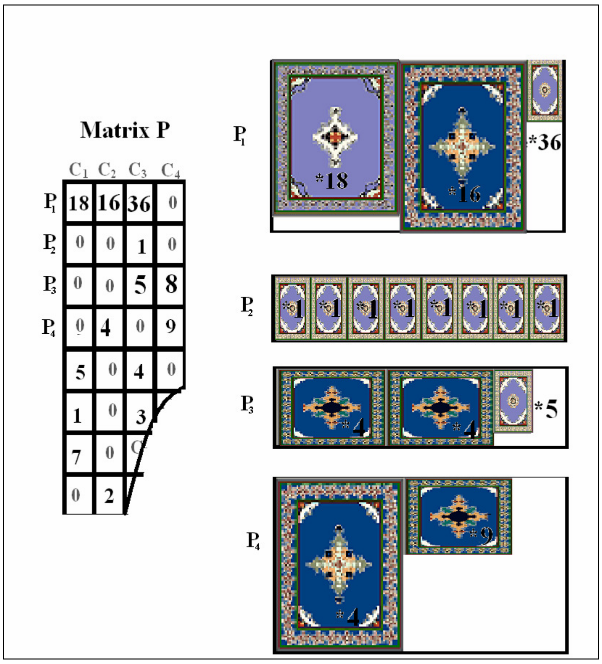

Figure 1- Pattern matrix of sample Q

Genetic Algorithm

Genetic algorithm is a search method based on the principle of natural selection and the survival of the fittest [4]. GA was first introduced by Holland [4]. A GA attempts to evolve a solution using a population of potential solutions (or individuals). New individuals are created by promising genetic material from one individual being passed to another by a process of breeding. Each solution has a fitness value associated with it. Our fitness value is derived from the cost function presented in next sections. The fitness of a solution determines how likely it is to be chosen to breed with another solution. Since GA has its foundations in genetics, terms from this field are used to describe the various features of a GA [4]. It is usual to call a solution a chromosome and the individual parts that make up the chromosome, a gene. For this problem a chromosome is a set of patterns and a gene is an individual pattern. The breeding between chromosomes is carried by two operators [4]. Crossover is the most important operator. It takes two chromosomes (parents) and transfers genetic material from them to produce two new chromosomes (children).

Coding and Initial Population

Based on matrix P the chromosomes matrix is generated.

Infact chromosomes matrix is the same as matrix P but the gens are index of the rows in matrix P which are randomly generated. All generated chromosomes should consist of all carpet types of customer order and the sum of carpets' length in each gens should be less than L_{path}. A sample of initial generation is shown in Figure 4.

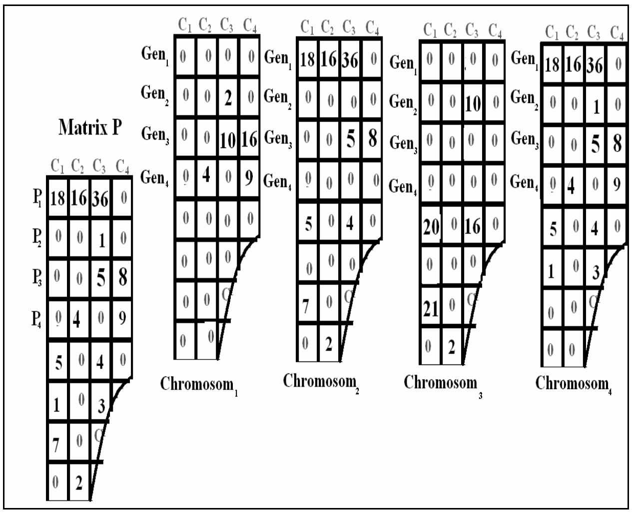

Figure 4- Sample of chromosome generation from pattern matrix

Fitness Function

After generating initial population, the fitness of each chromosome for next generation should be calculated. The fitness function check the number of carpets in each chromosome and compare it to customer order if the sum of each carpet type in chromosome is the same as customer order the schedule is achieved. Otherwise the fitness of chromosome is reduced corresponding to the difference between customer order and the number of carpets in chromosome.

Generate New Population

About 10 percent of new generation are directly selected from best chromosomes of last generation and for other genetic algorithm operation the chromosomes are selected by using Rolette round [5]. For crossover operation two selected chromosomes are cut from same random point and two offsprings are made. The mutation operator changes the position of random selected patterns randomly and makes new chromosome. The swap operator changes the position of two randomly selected patterns in selected chromosome and make new chromosome. Phenotype mutation operator is just used on the best chromosome in the last population. The operator is used for better space searching by small change in each gens index and calculating a fitness function. If the change gives a better fitness function, it is kept otherwise the last change is kept. Although the operator is very useful for space searching but it increases the calculating time hugely. The structure of the program is illustrated in Figure 5.

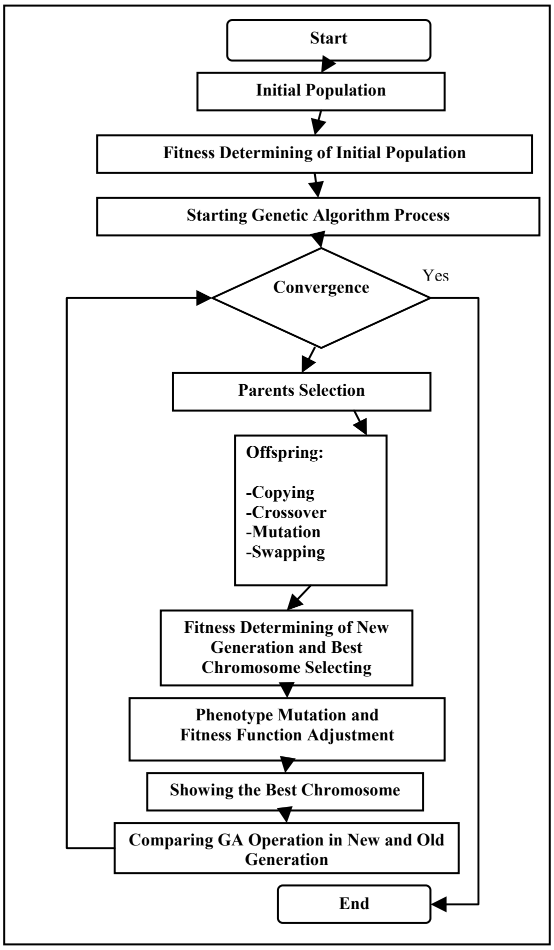

Figure 5- Genetic algorithm structure

Results

In Figure 6 the customer order on the program interface is shown. The orders and other data were provided by a carpet manufacturer in Iran. MATLAB programming software and its toolboxes were used to develop the integer and genetic algorithm programs.

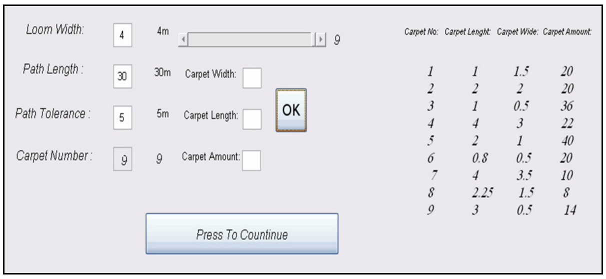

Figure 2- Program interface and customer order

The result of the customer order is illustrated in Figure 7.

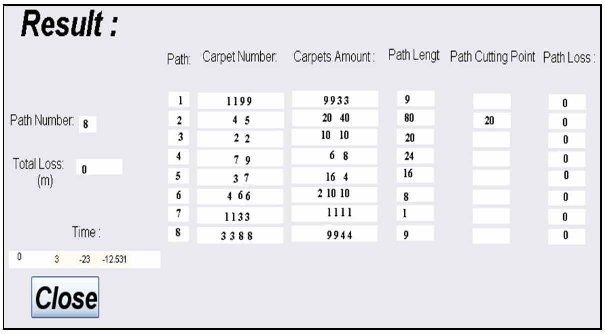

Figure 3- Result of customer order in Figure 6

Conclusion

The results show a reasonable improvement in the production efficiency of a carpet mill. However the time of running program directly depends on the carpet amount and types.

Reference

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