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CONSIDERING LAYOUT IN MANUFACTURING CELL FORMATION

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1. INTRODUCTION

This paper illustrates an innovative methodology to manufacturing cell formation and layout. Group technology is used in cell formation considering the joining of process and machines with similar activities. Layout design can be seen as a 2D cutting stock problem where the area usage minimization is the principal objective function where it is considering the physical space used in every machine. The methodology was used in a real problem and the results indicate a high efficiency to design manufacturing cells.

Group Technology (GT) aims to decompose a manufacturing system into subsystems or groups. The goal is to aggregating similar parts into families and dissimilar machines into cells such that movement of parts between similar machines that belongs to a cell is minimized. Group technology is applied to minimize material handling and relocation costs (others advantages) (Kusiak A. 1998). Cell formation is concerned with GT (Kusiak A. Chow W. 1998). Imply the use of a limited space to accommodate (maybe temporally) facilities. The proposed methodology unifies the GT formation and the floor plan Layout design optimization. Layout design problem is a very complex task. In this paper, the dimensionality of the problem can be reduced if GT is applied, so the layout optimization is considering only the machines in a group or formed cell. In the second section, a description of ART neural network and Genetic algorithm are considered. The third section is the experimental development. Discussions, conclusions, and future work will be given in the last section.

2. SOFT COMPUTING APPROACHES

In previous works, ART neural network has shown a better performance than other approaches (Elías Cerma 2007, Chandrasaekharaq & Rajagopalan, 1989). Layout optimization is related with 2D cutting problems.

2.1 Adaptive Resonance Theory (ART)

With the use of a neuronal network of type ART (Grossber & Carpenter, 1992) show in the figure 1, it can be obtained the manufacturing cells in his logical approach. The implicit categorization of the ART generates groups of machines, and the related process. This neuronal network (figure 1) creates the cluster based on a similitude parameter ρ , this parameter can be assorted between 0.1 and 0.9, and this parameter is located in the weight matrix that is used for the neuronal network to acquire memory. Due some past experimentation does not matter what number was used the answered is always the same.

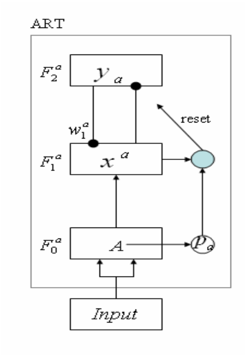


Figure 1. Basic Structure of ART

2.2 Genetic Algorithm

Genetic algorithms (GA) are the most used evolutionary algorithms. GA was developed by Holland 1975 and has grown as the most used paradigm to solve optimization problems (Mitsuo Gen 2000). There are several variants of the GA; nevertheless, all have four general procedures: evaluation of the individuals, selection of the best individuals (in a deterministic or stochastic way), crossover, and mutation of individuals (Goldberg, 1989). Every individual is a solution represented as a binary vector and a set of solutions represents a population of potential solutions or individuals making analogy to natural processes. The simple GA has binary vectors to represent parameters so real parameters representation requires a decoding procedure to use it in the evaluation procedure. The population begins with random solutions usually with low performance and high diversity. The evolutionary procedures (evaluation, selection, crossover and mutation) are applied of cyclical way, solutions of better performance are obtained and the diversity is lost. It is a more intelligent way to search solutions than ``trial and error" procedure. The following steps are involved to generate a near optimal solution in a sequence optimization problem.

Step1: Generate a random population.
Step 2: Evaluate every represented solution of the population using the neural network.
Step 3: Select the better evaluated individuals of the population.
Step 4: Generate a new population using crossover and mutation of the selected individuals.

Every individual represents the layout and the position on the area. The representation of the machine layout is by a permutation; that mean, an integer that represents the order assignation and the position on the area where a binary representation is used. Four positions are considered taking the angle of rotation of every layout. A 0, 90, 180, 270 grades of rotation are included. In genetic terms, every individual has two chromosomes: The order of assignation and the position on the surface. As an example, an individual to represent four machine layouts could have the following representation:

{4 2 3 1} A permutation of the assignation on area of every machine layout
[00 10 11 11]. A rotation description of every machine layout

The example indicates a sequence of selection of every machine layout; First, the fourth machine layout must be selected and apply a rotation of 0 grades before place on area. The second machine layout must be selected considering a rotation of 180 grades. On this manner, the final machine layout selected is the first one with a rotation of 270 grades. The problem consists to find a optimal sequence considering an optimal description of rotation to place on area. Usually there are more than four machine layouts and there are some area constrains must be considered like corridors and security zones.

3. EXPERIMENTATION

For the experimentation part where used the follow matrixes with are describe in table 1, each matrix where solve using the ART network to determinate the number of manufacturing cells, also the total are for located the manufacturing cells formed by art where invented depending of the amount of machines of each example. Using a genetic algorithm made for the optimization of the cutting problem, witch was modified for be used to solve the layout facility problem with the follow parameters in all experiments:

- Probability of mutation = 0.034
- Probability of crossover = 0.85
- Number of generations = 100
- Number of individuals = 200

Table 1. Matrices Used in Experimentation

Name	Number of machines	Number of process	Number of cells	Total area	Reference
Factory	25	27	25	30 x 16	Carrum 2005
Pump Machine	15	8	3	30 x 19	Created
Rajagopalan 1987	40	100	11	80 x 20	Rajagopalan 1987

Ones the number of cell where determinate, the total area for locate the cells where dived in the amount of cell formed. For entry of the area in the genetic algorithm it was used a binary matrix, in this matrix the 0 represents the empty spaces for located the cells and the 1 represent certain areas with are occupied with hallways or spaces than are already occupied for something, also each space in the matrix represent 1 meter for example if we introduce a matrix of size 5 x 10 this means that it a area of 50 meters square. For the entry of the machines it was used also a binary matrix where the dimensions of the matrix where represented by the size of the machine, also it was decided to located 2 extra meters to simulated the person who operated the machine an example of the introduction of 3 machines to the algorithm of size 6 x 5, 4 x 3 and 4 x 4 with the space for the worker is show in the figure 2.

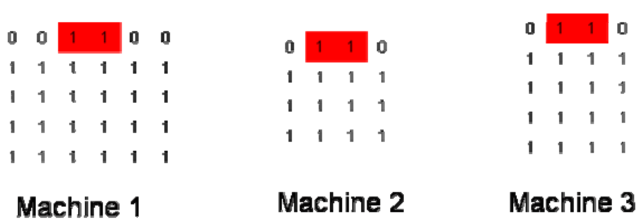


Figure 2. Example of the Entry for Machines in the Genetic Algorithm

Three examples have been considered. For the first example it was consider a real manufacturing plant where is real area is 30x16 meters, in this example there where no need to divide the area for each cell formed because in the solution given by ART each machine is a manufacturing cell, also in this example where located 2 hallways of size 2 x 30 with represent a real hallway located in the factory. Also in this factory only 3 types of machines they are sewing machines, irons machines and button sellers of size:

- 2 x 3 m.
- 2 x 1 ½ m.
- 2 x 2 m.

Ones the genetic algorithm is used to located the machines the final solution is shown in the figure 3.

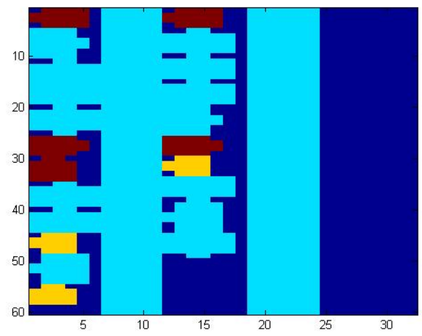


Figure 3. Final Solution to The Factory Problem

For the second example it was used a plant of size 30 x 19 that it was dived in 3 parts each one of size 10 x 19 because the solution of the neuronal network was three manufacturing cells (table 2), the first cell have 4 machines, the second cell have 3 machines and the third have only one machine, the size of each machine are show in the figure 4.

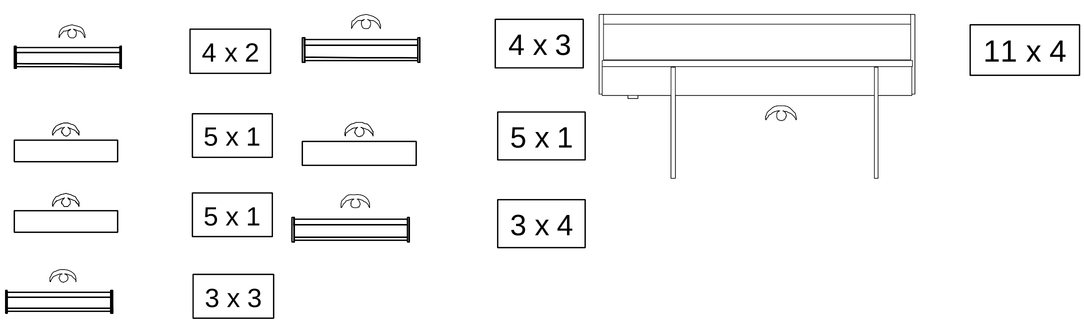


Figure 4. Size of the Machines Used in the Third Example

To run the genetic algorithm each manufacturing cell was introduced generating a separate solution for each one, for this case there where no considerations of hallways or any other thing, the final solution give by the genetic algorithm is show in the figure 5.

Table 2. Solution Give by ART for the Second Example

ART							
1	0	0	0	0	0	0	0
1	1	1	1	0	0	0	0
1	1	0	0	0	0	0	0
1	1	1	1	0	0	0	0
1	0	1	0	0	0	0	0
0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	1
0	0	0	0	0	1	0	0
0	0	0	0	1	1	1	0
0	0	0	0	0	1	1	0
0	0	0	0	1	0	1	0
0	0	0	0	1	0	0	0

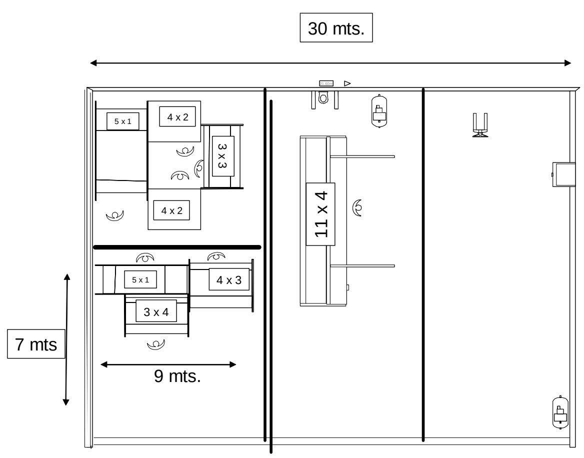


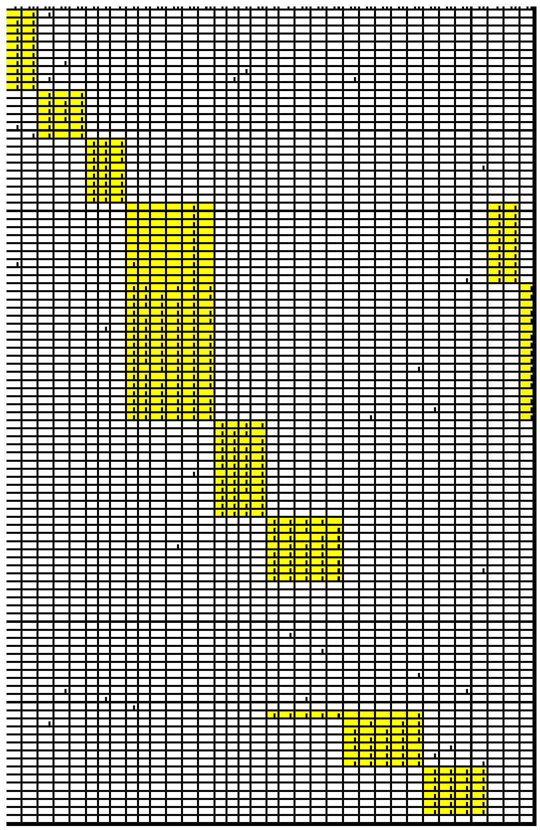
Figure 5. Final Solution of the Second Problem

In the last problem showed in the table 5, the solution give by art, it was used a matrix of size 80 x 20 for the total area this area where divide into 11 pieces so with that means that each entrance of the genetic algorithm will be of size 7 x 20 meters each in the figure 6 are show the machine sizes, also it was decided that each manufacturing cell located by the algorithm will be dived by a hallway of 2 x 1 meters in diagonal and 2 x 20 meters in horizontal division. Running the algorithm the final solution is shoed in the figure 7.

4. CONCLUSIONS

The dimensionality of the problem is reduced with GT. In layout optimization, it is considering a few machines of every group. The cell formation is inspired in GT, so some advantages of the solutions generated in GT are included with this proposal. A future work is the reuse of the solutions give with GT approach in conjunction with other soft computing and conventional techniques.

Table 3. Solution Give By ART to the Four Problems



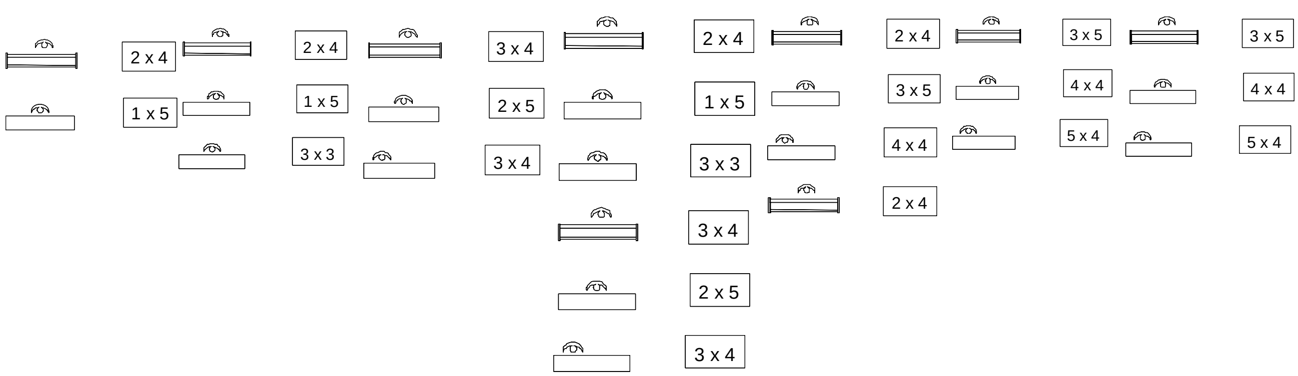


Figure 6. Size of the Machines for the Four Problems

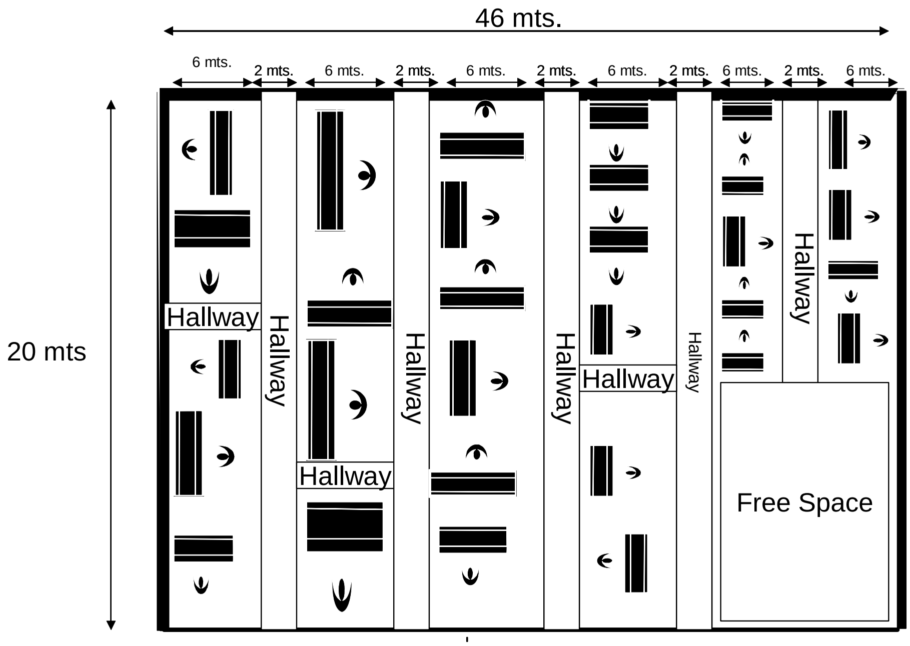


Figure 7. Layout Final Solution

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