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Title: *Group technology: Technique with comparisons*

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Once again, Congratulations on your CERMA 2007 acceptance. We are very excited to be able to include your research and ideas in the Conference, and we are looking forward to seeing you in September in Cuernavaca.

Best Regards

Prof. Andrea Magadán
Technical Committee Chair

Group technology: Technique with comparisons

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Abstract

In this paper it is presented a new technique to form group technology (GT), this methodology is based in the Hamming distance, also a comparison of deferent approaches to form GT is used to validate the proposed technique like neuronal networks, genetic algorithms, and other classic techniques. Results indicate a better performance of Hamming approach.

1. Introduction

In the today's manufacturing systems they are some different problems like high production time, numerous work inventory process (WIP), between others, one of the most used methodology to solve some problems like the production time and the WIP is group technology (GT) [1].

Group technology consists in identify and group families of parts from the product based in they similitude's. Each family has some similitude's this can be in the machine that is process it or in the design of the product, also GT have some benefits like [1]:

- Reduction of the starting time.
- Reduction of the WIP.
- Reduce the transportation cost between operations.
- Reductions in warehouse space.

Also this methodology is not only for solve the cell formation problem, GT is also used to improve the performance in the mix productions systems [2], also this methodology is been used to solve some logistic and distributions problems [3], and it is not only in the manufacturing systems where this methodology was be used also in image processing and recognition [3]. This paper will be presented in the followed sections. In the first one will be present the new technique and a summary of the deferent's techniques, then in section two will be presented the different techniques of evaluation and finally a comparison will be present with the results.

2. Summary of techniques

In this part of the paper will be presented a new technique, also will be presented a summary of classical and soft computing techniques.

Hamming method

This methodology was inspired in Hamming distance by observing the formation of clusters obtained by the result of the application this distance on a binary matrix. For the application of this technique have two cases the first one can be define as:

For quadratics matrix ($m = n$ *)*
Given an initial matrix of size $m * n$, in where m represent the machines and the n represent the process, were it is marked with 1 if the machine makes the process, distance of Hamming is calculated in the next form:

$$d_{ij} = \sum_{k=1}^{n} z(a_{ik}, a_{jk})$$

where

$$z(a_{ik}, a_{jk}) = \begin{cases} 1 & \text{if } a_{ik} \neq a_{jk} \\ 0 & \text{on the other way} \end{cases}$$

Where a new matrix d_{ij} of size $m * n$ ones created the new matrix it needs to obtain the values located under the sum $\sum_{i=1}^{m} d_{ij}$ for each process and select their position with respect to the machine, in this way, the process family (PF) for the machine family (MF) need to do the same proceeding but this time with respect to the machines of the matrix.

Example 1:

Process (columns) / Machines (rows)

0	1	0	1
1	0	1	0
0	1	0	1
1	0	1	0

Matrix 1 example1

Given this matrix of size 4 x 4 and applying the Hamming distance the resultant matrix will seems like this:

Process (columns) / Machines (rows)

0	4	0	4
4	0	4	0
0	4	0	4
4	0	4	0

Matrix 2

Start to obtain the values under the highest value of the sum $\sum_{i=1}^{m} d_{ij}$ for this example the values under 2. For the first process it is obtain the values and take this position with respect to the machines this must do it until finish all the process and it will be look like this:

Process (columns) / Machines (rows)

1	2	1	2
3	4	3	4

Matrix 3

It is taken the position that we already have it of the family witch belongs so the PF=1 & 3; 2 & 4. Now the same proceeding has to repeat with the machine families in the matrix 2 in this way we must follow the first line an take the values under 2 and take is position with respect to the machines there are left to finally obtain this:

Machines (columns) / Process (rows)

1	3
2	4
1	3
2	4

Matrix 4

Now we take the families in with belong so the final families will be MF= 1 & 3; 2 & 4.

Finally in this way we can have a new matrix using the PF and MF like this:

Process (columns) / Machines (rows)

0	0	1	1
0	0	1	1
1	1	0	0
1	1	0	0

Matrix 5

For cases of matrix non-quadratics ($m \neq n$)

Given an initial matrix of size $m * n$, in witch the m represent the machines and the n process in were is marked with 1 if the machine makes the process. The matrix of the distance of Hamming is created of the next form:

$$d_{ij} = \sum_{k=1}^{n} z(a_{ik}, a_{jk})$$

where

$$z(a_{ik}, a_{jk}) = \begin{cases} 1 & \text{if } a_{ik} \neq a_{jk} \\ 0 & \text{on the other way} \end{cases}$$

In this way it is create a matrix d_{ij} of size $n * n$ to obtain the PF it need to be selected one part of the matrix d_{ij} this part must be of size $n * n - 1$ and repeat the same steps using in the quadratic matrix. For the formation of MF need s to be selected a part of the matrix d_{ij} this part of the matrix must be of size $m * m$ and make the same proceeding.

Similar Coefficients:

This technique is based in the similitude between two machines this similitude is defined as [3]:

$$s_{ij} = \frac{\sum_{k=1}^{n} d^{1}(a_{ik}, a_{jk})}{\sum_{k=1}^{n} d^{2}(a_{ik}, a_{jk})}$$

Where

$$d^1(a_{ik},a_{jk}) = \begin{cases} 1 \text{ if } a_{ik} = a_{jk} = 1 \\ 0 \text{ on the other hand} \end{cases}$$

$$d^2(a_{ik},a_{jk}) = \begin{cases} 0 \text{ if } a_{ik} = a_{jk} = 0 \\ 1 \text{ on the other hand} \end{cases}$$

The GT will be formed when the families have the same coefficient of similarities.

Sorting-based algorithms or ROC

This technique is based on classify from more to less all the columns and the lines of the initial matrix using this expression [3]:

$$p_i = \sum_{k=1}^{n} a_{ik} 2^{n-k}$$

The P-median model

This technique is used to group parts into PF, this technique use the concept of distance between parts d_{ij}, this distance can be defined in two deferments ways one is the hamming distance and the other is the distance Mintowski for this work it is used the hamming distance. The GT problem can be solved used the follow binary program:

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij} x_{ij}$$

Subject to:

$$\sum_{j=1}^{n} x_{ij} = 1; \; i = 1,....n$$

$$\sum_{j=1}^{n} x_{jj} = p$$

$$x_{ij} \le x_{jj} \qquad \text{for all } i = 1,....,n; j = 1,.....,n$$

$$x_{ij} = 0,1 \qquad \text{for all } \begin{cases} i = 1,....,n \\ j = 1,....,n \end{cases}$$

Where p is the specify number of PF.

ART

The figure 1 shows the general structure of an artificial neuronal network ART-1 [4][5].

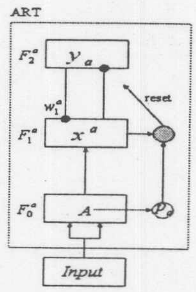

Figure 1. Basic structure of the ART-1

Genetics Algorithms

The type of genetic algorithm (GA) used to form GT was the ranking order genetic algorithm [6] the scheme is presented below:

- Initialized the population random.
- Evaluate each one of the solutions and assign the fitness.
- Choose the population witch have the best fitness.
- Mutate and make crossover to al solutions chosen.
- Repeat all this one considerate number of times

For see the behavior of the partially separable clusters in this part of the experimentation was used the ranking order genetic algorithm with the follows parameters:

- Number of individuals = 1000
- Crossover PMX
- Mutation interchange
- Number of generations = 100
- Crossover probability = .85
- Mutation probability = 0.1

The evaluation function is a classic method used to form group technology called Bond Energy algorithm given by:

$$MIN \; ME$$

$$ME = 1/2 \sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij} \left[a_{i,j-1} + a_{i,j+1} + a_{i-1,j} + a_{i+1,j} \right]$$

3. Description of techniques of evaluation

Hamming Distance

This criterion of comparison consist in select the matrix with less distance and is given by:

$$d_{ij} = \sum_{k=1}^{n} z\left(a_{ik}, a_{jk}\right)$$

where

$$z\left(a_{ik}, a_{jk}\right) = \begin{cases} 1 & \text{if } a_{ik} \neq a_{jk} \\ 0 & \text{on the other way} \end{cases}$$

Mitowski Distance

This criterion of comparison consist in select the matrix with less distance and is given by:

$$d_{ij} = \left[\sum_{k=1}^{n} \left| a_{ik} - a_{jk} \right|^{r} \right]^{1/r}$$

Where r is an entire positive and n is the number of parts.

Mitowski Euclidean Distance

This criterion of comparison consist in select the matrix with less distance and is given by:

$$d_{ij} = \left[\sum_{k=1}^{n} \left| a_{ik} - a_{jk} \right|^{2} \right]^{1/2}$$

Where n is the number of parts.

Bond Energy

This criterion of comparison consist in select the matrix with most ME and is given by:

$$ME = 1/2 \sum_{i=1}^{m} \sum_{j=1}^{n} a_{ij} \left[a_{i,j-1} + a_{i,j+1} + a_{i-1,j} + a_{i+1,j} \right]$$

Criteria of efficiency

Using the criteria of efficiency employ by Chandrasaekharaq & Rajagopalan [7]. Where we use the global efficiency denoted by η this method is calculate in the follow way:

$$\eta = q n_1 + (1-q) n_2$$

Where:

$$n_1 = \frac{e_d}{\sum_{r=1}^{k} M_1 N_1}$$

$$n_2 = 1 - \frac{e_0}{mn - \sum_{r=1}^{k} M_1 N_1}$$

In this method it is selected the matrix with more global efficiency.

Efficacy Criteria

Using criteria of efficiency employ by Chandrasaekharaq & Rajagopalan [8]. As the criteria efficacy we select the matrix with more criteria of efficacy and is given by:

$$\mu = \frac{N_1 - N_1^{Out}}{N_1 + N_0^{In}}$$

Distance to diagonal

This method consists in found the less distance between the group formed and the diagonal matrix.

Machine Utilization

This method consist in select the most machine utilization [9]:

$$Mu = \frac{e_1}{\sum_{k=1}^{g} j_k i_k}$$

Group efficiency

This method consist in select the most Group Efficiency [9]:

$$Ge = 0.5Mu + .5[1 - \frac{e_e}{(MN - \sum_{k=1}^{g} j_k i_k)}$$

4. Experimentation

To make the comparisons between techniques and techniques of evaluation were selected nine different matrixes they are listed below:

Name	Size	Reference
Kusiak	4x5	Kusiak 1998 [3]
Problem B	6x7	Created
Problem C	6x7	created
Rajagopalan	6x11	Rajagopalan 1989 [7]
Pump Machine	15x8	Internet
Factory	25x27	Carrum 2005 [10][11]
Carrie	20x35	Carrie 1973 [12]
Rajagopalan 1989	24x40	Rajagopalan 1989 [8]
Rajagopalan 1987	40x100	Rajagopalan 1987 [7]

Table 1 matrix of experimentation

From the nine different matrixes in this work where obtain several tables of results showed in the annexes of this paper. To select the techniques that made a better grouping selecting those ones who have been more scored in the techniques of evaluation, this was made selecting between all the techniques those how have better evaluation in each matrix (table 2)

Name	Winner
Kusiak	Genetic Algorithm
Problem B	ART, ROC, P-median
Problem C	Genetic Algorithm
Rajagopalan	Genetic Algorithm , ROC
Pump Machine	Genetic Algorithm, Hamming Method
Factory	ART, ROC, Hamming Method
Carrie	ART, ROC, Similar Coefficients, Hamming Method
Rajagopalan 1989	ART, ROC, Genetic Algorithm, Similar Coefficients, Hamming Method
Rajagopalan 1987	Genetic Algorithm, Hamming Method

Table 2 experimentations results

5. Conclusion and Future Work

Where can find that the better techniques to form group technology based in the size of the matrix and in the better group evaluation are:

- Genetic Algorithm
- ART
- Hamming Method

As future work it is necessary to make an autonomous technique, make a new ways of using the genetics algorithms combined with other techniques or make hybrids techniques to use more parameters like cost, time of movement of the pieces, and make some simulations to se how it is the behavior of the new technique.

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Appendix

	Kusiak 4x5						
	Inicial	ART	ROC	GA	Pmedia	SC	Hamming
Distancia Hamming	48	48	48	48	48	48	48
Distancia Minkowski	48	48	48	48	48	48	48
Distancia Minkowski Euclidiana	84	84	84	84	84	84	84
Efficacy	14	14	14	10	10	10	10
Rajagopalan	-1.2	-1.2	-1.2	-0.64	-0.64	-0.64	-0.64
Dr. Luis	18	22.66	22.66	6.66	8	8	8
Bond Energy	0.5	0.5	0.5	4.5	4.5	4.5	4.5

	Problema B 6x7						
	Inicial	ART	ROC	GA	Pmedia	SC	Hamming
Distancia Hamming	80	80	80	80	80	80	80
Distancia Minkowski	80	80	80	80	80	80	80
Distancia Minkowski Euclidiana	80	80	80	80	80	80	80
Efficacy	11	10	10	12	10	11	12
Rajagopalan	-1.5	-1.4	-1.4	-1.6	-1.4	-1.5	-1.6
Dr. Luis	10.2	5.4	5.4	10.2	5.4	10.2	10.2
Bond Energy	0	0.5	0.5	0.5	0.5	0	0.5

	Problema C 6x7						
	Inicial	ART	ROC	GA	Pmedia	SC	Hamming
Distancia Hamming	128	128	128	128	128	128	128
Distancia Minkowski	128	128	128	128	128	128	128
Distancia Minkowski Euclidiana	240	240	240	240	240	240	240
Efficacy	17	16	21	21	15	21	17
Rajagopalan	-1.4	-1.3	-1.8	-1.8	-1.2	-1.8	-1.4
Dr. Luis	29.2	15.6	44	49.2	16	44	20
Bond Energy	1	5.5	5.5	7.5	5.5	5.5	3.5

	Brown 6x7						
	Inicial	ART	ROC	GA	Pmedia	SC	Hamming
Distancia Hamming	328	328	328	328	328	328	328
Distancia Minkowski	328	328	328	328	328	328	328
Distancia Minkowski Euclidiana	556	556	556	556	556	556	556
Efficacy	30	30	32	31	30	30	31
Rajagopalan	-2.68	-2.68	-2.8	-2.74	-2.68	-2.68	-2.74
Dr. Luis	93	93	93	74	93	93	91
Bond Energy	5.5	5.5	7.5	7.5	5.5	5.5	6

	Pump Machine 15x8						
	Inicial	ART	ROC	GA	Pmedia	SC	Hamming
Distancia Hamming	302	302	302	302	302	302	302
Distancia Minkowski	302	302	302	302	302	302	302
Distancia Minkowski Euclidiana	999	999	99	999	999	999	999
Efficacy	33	33	33	33	33	33	33
Rajagopalan	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9	-1.9
Dr. Luis	58	39	67	105	58	58	36.5
Bond Energy	3	13	10	15	3	3	12.5

	Planta 25x27						
	Inicial	ART	ROC	GA	Pmedia	SC	Hamming
Distancia Hamming	1532	1532	1532	1532	0	1532	1532
Distancia Minkowski	1532	1532	1532	1532	0	1532	1532
Distancia Minkowski Euclidiana	1922	1922	1922	1922	0	1922	1922
Efficacy	54.96	55	55	56.96	0	54.96	55
Rajagopalan	-7.74	-7.74	-7.54	-7.8	0	-7.74	-7.74
Dr. Luis	166.25	87.6	87.6	302.8	0	149.33	87.6
Bond Energy	2.5	4.5	4.5	4.5	0	4	4.5

	Carrie 20x35						
	Inicial	ART	ROC	GA	Pmedia	SC	Hamming
Distancia Hamming	4344	4344	4344	4344	0	4344	4344
Distancia Minkowski	4344	4344	4344	4344	0	4344	4344
Distancia Minkowski Euclidiana	29324	29324	29324	29324	0	29324	29324
Efficacy	154	152	152	154	0	152	152
Rajagopalan	-5.56	-5.49	-5.49	-5.56	0	-5.49	-5.49
Dr. Luis	883.52	433.11	433.11	883.52	0	433.11	433.11
Bond Energy	20	96.5	96.5	20	0	96.5	96.5

	Rajagopalan (1989) 24x40						
	Inicial	ART	ROC	GA	Pmedia	SC	Hamming
Distancia Hamming	5330	5330	5330	5330	0	5330	5330
Distancia Minkowski	5330	5330	5330	5330	0	5330	5330
Distancia Minkowski Euclidiana	30031	30031	30031	30031	0	30031	30031
Efficacy	151	151	151	152	0	152	151
Rajagopalan	-6.7	-6.7	-6.7	-6.81	0	-6.81	-6.7
Dr. Luis	1064	89807179	89807179	1092.1	0	1092.1	89807179
Bond Energy	23	99	99	77.5	0	77.5	99

	Rajagopalan (1987) 100x40						
	Inicial	ART	ROC	GA	Pmedia	SC	Hamming
Distancia Hamming	29736	29570	0	29736	0	0	29570
Distancia Minkowski	29736	29570	0	29736	0	0	29570
Distancia Minkowski Euclidiana	325988	322499	0	325988	0	0	322499
Efficacy	0	0	0	0	0	0	0
Rajagopalan	0	0	0	0	0	0	0
Dr. Luis	5265.8	4961.3	0	5496.8	0	0	4961.3
Bond Energy	78.5	280.5	0	191.5	0	0	280.5