MATLAB Based Manhattan Distance Matrix Method to Solve Cell Formation Problems

K. V. Durga Rajesh, A. Shanmukh Krishna, V. Samba Siva Rao, U.V.S. Phanindra, B. Kamal

***Abstract*: The Cell Formation Technique in Cellular Manufacturing System (CMS) is mainly focused in this paper, which is a Group Technology (GT) based application. The vital step in CMS design is the Cell Formation (CF). The main task of Formation of Cells is to combine parts and machines. A new heuristic approach was proposed in this paper to achieve CF based on the Manhattan Distance Matrix (MDM) Method. MATLAB CODE is developed for the method proposed above. As a measure of performance Grouping Efficacy (GE) is considered. Computational works were conducted with case study problem set taken from standard article. Results after computation determine that the GE performance of our heuristic approach is finer or equal to the other well-known active algorithms ROC & ROC-2.**

***Index Terms*: Cellular Manufacturing System, Cell Formation, Group Technology, Grouping Efficacy, Manhattan Distance Matrix.**

I. INTRODUCTION

À manufacturing ideology that discusses the combining of common parts that are recognized according to their design and production similarities known as Group Technology (GT). The practice of using GT in a machining tool enhances product goodness, lead time, productivity, resource use including space and also scales down the throughput time, cost of material lifting and WIP inventory.

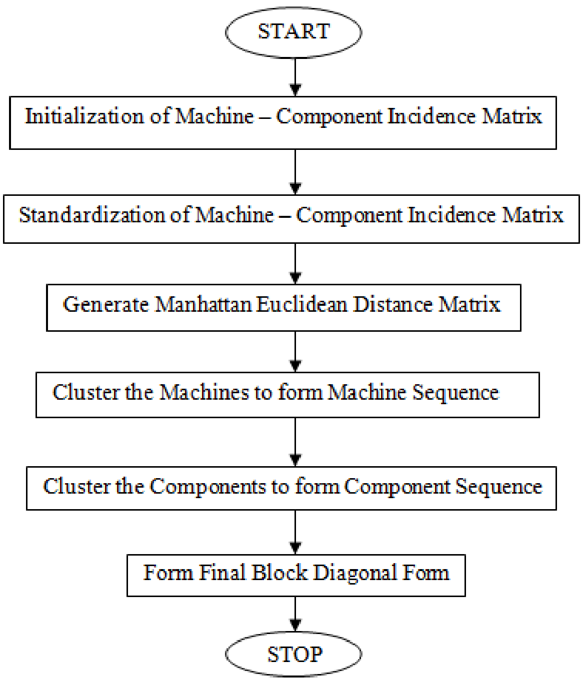
Geometry of Taxicab is a form of geometry whereby a new measure is substituted by the usual distance function or metric for euclidean geometry, which sums up the total difference of its cartesian coordinates between two points [1]. Taxicab metrics are also called rectilinear distance, L_1 distance and L_1 norm and the corresponding variation in geometric names. It is known as zigzag distance, block city distance, Manhattan distance or the Manhattan length. Since the 18th century, geometry has been used for regression analysis and is often known as LASSO today. The Manhattan distance work computes the separation starting with one information point then onto the next if a framework is pursued – like a way. The separation between two things in Manhattan is the total of their relating contrasts in segments. The formula for this distance from point X=(X_1, X_2, etc.) to point Y=(Y_1, Y_2, etc.) is:

$$d=\sum_{i=1}^{n} |x_i - y_i|$$

Recently Dipak Laha and Manash Hazarika [2] proposed a best approach based on Euclidean distance matrix. In general, various kinds of Euclidean distance matrices are available. From that we have considered Manhattan Distance Matrix and we applied to Cell Formation Problems to design cells. To evaluate the effectiveness of solution obtained, Grouping Efficacy (GE) is considered and suggested by kumar and Chandrasekharan.

II. STEPS IN MANHATTAN DISTANCE MATRIX

The Steps involved in Manhattan Distance Matrix Method is shown in flow chart mentioned below.



The distance between two machines in Manhattan speaks for machines and can be find by the relationship shown below.

$$D_{xy}=\sum_{i=1}^{m} |(b_{ix} - b_{iy})|$$

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III. APPLICATION OF MANHATTAN DISTANCE MATRIX METHOD TO CELL FORMATION PROBLEM

Consider a 5 Machines problem and 7 Parts problem (King and Nakornchai (1982)) shown in Table I. We used Manhattan Distance Matrix algorithm steps for the cell formation problem using manual method and using MATLAB.

Table I: (5 x 7) Machine-Part Incidence Matrix

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

A. USING MANUAL METHOD

After Initialization of (5x7) matrix, find standardized matrix by using procedure developed by Wafik et al [3]. For Table-I, for machines count number of ones in each row and find average of each row; the same is shown below as A_1 and $\bar{A}_1$.

Then find σ_i for all rows using $\sigma_i^2 = \bar{A}_i - \bar{A}_i^2$

$A_1 = 4$; $\bar{A}_1 = 4/7 = 0.571$; $\sigma_1 = 0.4944$

$A_2 = 2$; $\bar{A}_2 = 2/7 = 0.2857$; $\sigma_2 = 0.4517$

$A_3 = 4$; $\bar{A}_3 = 4/7 = 0.571$; $\sigma_3 = 0.494$

$A_4 = 3$; $\bar{A}_4 = 3/7 = 0.4285$; $\sigma_4 = 0.4948$

$A_5 = 3$; $\bar{A}_5 = 3/7 = 0.4285$; $\sigma_5 = 0.4948$

Now find b_{ij} values for all columns up to 7.

$b_{ji} = (c_{ji} - \bar{A}_i) / \sigma_i$

For column 1 'b' values obtained are,

$b_{11} = (a_{11} - \bar{A}_1) / \sigma_1 = -1.154$;

$b_{21} = (a_{21} - \bar{A}_1) / \sigma_1 = 0.867$;

$b_{31} = (a_{31} - \bar{A}_1) / \sigma_1 = -1.154$;

$b_{41} = (a_{41} - \bar{A}_1) / \sigma_1 = 0.867$;

$b_{51} = (a_{51} - \bar{A}_1) / \sigma_1 = 0.867$;

$b_{61} = (a_{61} - \bar{A}_1) / \sigma_1 = 0.867$;

$b_{71} = (a_{71} - \bar{A}_1) / \sigma_1 = -1.154$

Similarly compute for all columns of the matrix and the obtained B-Matrix is shown in Table II.

Table II: B - Matrix for (5 x 7) Problem

-1.154	1.5813	0.867	-0.866	1.155
0.867	-0.632	-1.154	1.155	-0.866
-1.154	1.5813	0.867	-0.866	-0.866
0.867	-0.632	-1.154	1.155	-0.866
0.867	-0.632	-1.154	-0.866	1.155
0.867	-0.632	0.867	1.155	-0.866
-1.154	-0.632	0.867	-0.866	1.155

Formula of Manhattan Distance Matrix

$$d_{12} = \sum_{i=1}^{7} |(b_{i1} - b_{i2})|$$

Distance Matrix obtained for machines is shown in Table III. After that similar procedure is applied to parts, Distance matrix (D-Matrix) obtained for parts is shown in Table IV.

Table III: D - Matrix for Machines

MACHINES	M1	M2	M3	M4	M5
M1	0	24.2	24.5	3.5	19.8
M2	24.2	0	6.33	21.7	12.7
M3	24.5	6.33	0	19.8	11.7
M4	3.5	21.7	19.8	0	24.5
M5	19.8	12.7	11.7	24.5	0

Table IV: D - Matrix for Parts

PARTS	P1	P2	P3	P4	P5	P6	P7
P1	0	20	3.33	20	11.7	16.7	3.33
P2	20	0	16.7	0	8.33	3.33	16.7
P3	3.33	16.7	0	16.7	16.7	11.7	8.33
P4	20	0	16.7	0	8.33	3.33	16.7
P5	11.7	8.33	16.7	8.33	0	11.7	8.33
P6	16.7	3.33	11.7	3.33	11.7	0	11.7
P7	3.33	16.7	8.33	16.7	8.33	11.7	0

B. USING MATLAB

For the same (5 x 7) matrix shown in Table I, Source code is developed using Basic Proprietary / Scripting Language. The same is run through MATLAB. The source code is shown below.

```
For Machines:
A=[0 1 1 0 1;1 0 0 1 0;0 1 1 0 0;1 0 0 1 0;1 0 0 0 1;1 0 1 1 0;0 0 1 0 1]
for i=1:5
c(i)=0;
for j=1:7
c(i)=c(i)+A(j,i);
end
end
G=[c(1) c(2) c(3) c(4) c(5)]
for i=1:5
   P(i)=c(i)/7;
end
H=[P(1) P(2) P(3) P(4) P(5)]
for i=1:5
   S(i)=(P(i)-P(i)^2)^(1/2);
end
I=[S(1) S(2) S(3) S(4) S(5)]
for i=1:7
   for j=1:5
      b(i,j)=(A(i,j)-P(j))/S(j);
   end
end
```


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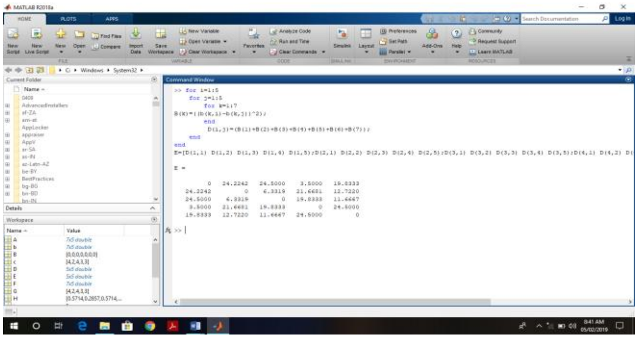
```
F=[b(1,1) b(1,2) b(1,3) b(1,4) b(1,5);b(2,1) b(2,2) b(2,3) b(2,4) b(2,5);b(3,1) b(3,2) b(3,3) b(3,4) b(3,5);b(4,1) b(4,2) b(4,3) b(4,4) b(4,5);b(5,1) b(5,2) b(5,3) b(5,4) b(5,5);b(6,1) b(6,2) b(6,3) b(6,4) b(6,5);b(7,1) b(7,2) b(7,3) b(7,4) b(7,5)]
for i=1:5
   for j=1:5
      for k=1:7
B(k)=abs(b(k,i)-b(k,j));
      end
D(i,j)=(B(1)+B(2)+B(3)+B(4)+B(5)+B(6)+B(7));
end
end
E=[D(1,1) D(1,2) D(1,3) D(1,4) D(1,5);D(2,1) D(2,2) D(2,3) D(2,4) D(2,5);D(3,1) D(3,2) D(3,3) D(3,4) D(3,5);D(4,1) D(4,2) D(4,3) D(4,4) D(4,5);D(5,1) D(5,2) D(5,3) D(5,4) D(5,5)]
```

Distance Matrix obtained for machines through MATLAB is shown in Table V.

Table V: D - Matrix for Machines obtained in MATLAB

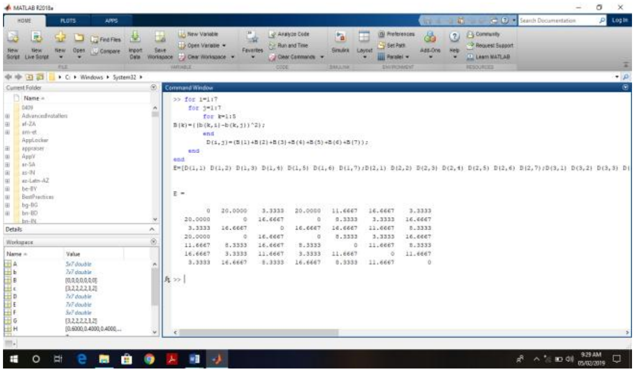


For Parts:

```
A=[0 1 0 1 1 1 0;1 0 1 0 0 0 0;1 0 1 0 0 1 1;0 1 0 1 0 1 0;1 0 0 0 1 0 1]
for i=1:7
c(i)=0;
for j=1:5
c(i)=c(i)+A(j,i);
end
end
G=[c(1) c(2) c(3) c(4) c(5) c(6) c(7)]
for i=1:7
   P(i)=c(i)/5;
end
H=[P(1) P(2) P(3) P(4) P(5) P(6) P(7)]
for i=1:7
   S(i)=(P(i)-P(i)^2)^(1/2);
end
I=[S(1) S(2) S(3) S(4) S(5) S(6) S(7)]
for i=1:5
for j=1:7
      b(i,j)=(A(i,j)-P(j))/S(j);
end
end
F=[b(1,1) b(1,2) b(1,3) b(1,4) b(1,5) b(1,6) b(1,7);b(2,1) b(2,2) b(2,3) b(2,4) b(2,5) b(2,6) b(2,7);b(3,1) b(3,2) b(3,3) b(3,4) b(3,5) b(3,6) b(3,7);b(4,1) b(4,2) b(4,3) b(4,4) b(4,5) b(4,6) b(4,7);b(5,1) b(5,2) b(5,3) b(5,4) b(5,5) b(5,6) b(5,7)]
for i=1:7
for j=1:7
for k=1:5
B(k)=((b(k,i)-b(k,j))^2);
end
      D(i,j)=(B(1)+B(2)+B(3)+B(4)+B(5)+B(6)+B(7));
end
end
E=[D(1,1) D(1,2) D(1,3) D(1,4) D(1,5) D(1,6) D(1,7);D(2,1) D(2,2) D(2,3) D(2,4) D(2,5) D(2,6) D(2,7);D(3,1) D(3,2) D(3,3) D(3,4) D(3,5) D(3,6) D(3,7);D(4,1) D(4,2) D(4,3) D(4,4) D(4,5) D(4,6) D(4,7);D(5,1) D(5,2) D(5,3) D(5,4) D(5,5) D(5,6) D(5,7);D(6,1) D(6,2) D(6,3) D(6,4) D(6,5) D(6,6) D(6,7);D(7,1) D(7,2) D(7,3) D(7,4) D(7,5) D(7,6) D(7,7)]
```

Distance Matrix obtained for parts through MATLAB is shown in Table VI.

Table VI: D - Matrix for Parts obtained in MATLAB



It is observed that Distance matrices obtained from both manual methods and MATLAB are same. Now manually logical machine sequence and part sequence are identified from distance matrix by taking minimum distance and then form final Block Diagonal Form (BDF). Final BDF obtained is shown in Table VII.

Table VII: BDF for (5x7) Problem

		Components						
		2	4	6	5	1	3	7
Machines	1	1	1	1	1			
	4	1	1	1				
	2					1	1	
	3			1		1	1	1
	5				1	1		1

From above BDF, it is observed that two cells are formed with **2** Exceptional Elements (EE).

IV. VALIDATION OF PROPOSED MEDM

To examine the performance of proposed Manhattan Distance Matrix (MDM) Method the Performance parameter Grouping Efficacy (GE) is considered and computed to ROC, ROC-2 and MDM techniques for a (7x8) Case Study [4] Problem. GE obtained for above said methods are shown in below Table VIII.

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Table VII: Performance Parameter for 3 Methods

Techniques	Performance Parameter
	GE
ROC	53.20%
ROC-2	42.40%
MDM	63.63%

From Table VII, it is observed that GE is increased to **10.43%** for proposed MDM compared with ROC technique. GE is increased to **21.23%** for proposed method MDM contrasted with ROC-2 technique.

V. CONCLUSION

The basic intention of this paper is to achieve best machine and part cellular efficiency with the use of the Manhattan Distance Matrix in cellular production systems. We found that for Manhattan Distance Matrix using manual method and MATLAB distance matrices obtained are same for cell formation problems. Computational results of suggested Manhattan Distance Matrix in comparison with well-known existing methods ROC and ROC-2 for case study problem are presented using Performance Parameter Grouping Efficacy. This shows that the suggested algorithm gives better results for most cases among existing algorithms. Using MATLAB, Computation time for proposed algorithm is reduced. We have developed MATLAB Code for Manhattan Distance Matrix from which we got final solution within less time which in turn takes long time in manual processing.

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