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Comparison of Different Clustering Methods for Cellular Manufacturing: A Case of Gym Centre

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Abstract

Cellular manufacturing (CM) is a method of designing the plant layout which takes advantage of similar parts/tasks to form machine cells within a particular part family. CM formation has been studied by many manufacturing firms in order to give quick response to changing customer demand because it helps firms to boost their productivity. Although CM is applied to the manufacturing layouts generally, service systems can also take advantage of CM approach. In this study, a layout of a gym centre is considered as a case study. The considered gym centre includes 33 sport equipment (machines) and 10 activity program (parts). Each program follows a pre-determined equipment order for each customer. The problem is location the equipment for each program to use the layout efficiently and decrease the distance between machines. To solve this problem, a three-phased solution approach is applied in this paper. In the first phase, the current situation is analysed via calculating the distance of each program. Then, two clustering methods namely rank ordering clustering (ROC) and average linkage clustering (ALC) are applied respectively. In the final phase, the results are compared with the current situation to show the improvements. As a result, the space utilization is increased by 30% and the distance between machines is decreased by averagely 35% averagely.

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Keywords: Average linkage clustering; Cellular manufacturing; Gym centre; Layout design; Rank ordering clustering.

1. Introduction

Group technology (GT) has been studied by many manufacturing firms in order to react as quickly as possible to meet altering customer demand and assisting companies to boost their productivity. GT can be considered as wide concept, which deals with manufacturing, marketing, production management and planning. By application of GT, it is aimed that having benefit from grouping similar concepts in every stage of manufacturing in order to cope with problems and incline productivity. CM is the part of the GT. Purpose of CM is to cluster machines and parts into production cells in order to minimize movement of parts to other cells for processing and maximizing the load of

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each cell machines during the operations (Utkina, Batsyn, and Batsyna 2018). The general structure of CM is expressed in three main approaches which are parts families are generated with respect to processing requirements, manufacturing cells constructed in accordance with clustered machines and part families are attended to cells (Papaioannou and Wilson 2010). There are several approaches to solve CM such as implementation of immune system based algorithm. An immune system based algorithm provides an optimum number of cell and tested on 67 test problem from literature (Ulutas 2018). Another approach in aforementioned aspect is the application of genetic algorithm which is tested on randomly generated small problems solved by LINGO 9 software (Shahdi-Pashaki, Teymourian, and Tavakkoli-Moghaddam 2018). From the real life application of CM, scheduling and configuration of the operating theatre can be given as instance. In the given example for real life application, multi-objective binary programming model to examine the effect of tray configuration and inventory management of needed surgical instruments for scheduling operation room (Keyhanian, Ahmadi, and Karimi 2018). In order to achieve efficient production and service, clustering the product that requires same kind of resources become an important planning strategy. In this study ROC and ALC are applied to group similar activities together and thereafter create cells. ALC algorithm based on the calculated distance of two part families by utilizing average similarity of all parts in the each cluster (Huang et al. 2018). For instance, ALC algorithm is applied to corruption perception among 134 countries and its relation with economy is presented by taken gross domestic product per capita for each state into consideration (Paulus and Kristoufek 2015). Another example for ALC algorithm deals with clustering variants of product with respect to networked operation sequence. In proposed study, aim is to provide similarity coefficient of products in flexible order of processing operations (Navaei and ElMaraghy 2016). When it comes to ROC method, it can be said that algorithm based on the sorting the rows and columns in declined order with respect to binary weight working principle (King 1980). ROC algorithm is also utilized in the process hybridization in literature. For instance, ROC is used as local search part of the hybrid principle component analysis and hybrid agglomerative clustering algorithm application on the machine-component cell formation problem (Pachayappan and Panneerselvam 2018). Another approach for utilization of ROC includes the modification. In this aspect, modified ROC algorithm is generated in order to optimize manufacturing process which contains independent variables and reshape the machine component data ,that formation of same work load cell based on (Amruthnath and Gupta 2016). In this study, cellular manufacturing system adaptation to service system is examined. In this respect, Gym centre is taken as instance. In order to accomplish the assignment of cells, sport tools which are included in most commonly utilized programs are grouped by taken similarity into consideration. ROC and ALC algorithms are applied to create cell in the Gym centre, their performances are compared according to their capacity to lessen total distances between sports implements of athletes walk in one program. Firstly, the methods used in the study will be explained and each generated cell design with respect to the methods will be given. Finally, main conclusions are draws in the last Section.

2. ROC and ALC Clustering Approaches for Cell Formation

Cell Formation (CF) is one of the most important methods in Cellular Manufacturing System (CMS). The main purpose of CF is to create separated machine groups in which parts are processed with maximum interactions than the other cells. In CF there are various approaches to cell formation and may fall under one of the three major classifications: array-based clustering, hierarchical clustering and non- hierarchical clustering (Arora, Haleem, and Singh 2011). Therefore, in this study, ROC which falls under array- based clustering techniques and ALC falls under hierarchical clustering techniques were applied.

2.1. ROC Algorithm

ROC method is one of the most common methods for generating cells that take the machine-part matrix as input. The computational simplicity of the ROC method plays a big role in its preference. Steps of ROC are as follow (Amruthnath and Gupta 2016):

Step 1: Creating an initial matrix b_{ij} (n*m matrix indicates binary number for n parts and m machines).
Step 2: For each row compute Eq. (1),

$$\sum_{i=1}^{m} \mathrm{bij} * 2^{m-j} \quad (1)$$

Step 3: Change order of the rows in descending order with respect to computed numbers.

Step 4: Compute Eq.(2) for each row of j.

$$\sum_{i=1}^{n} \text{bij} * 2^{m-j} \tag{2}$$

Step 5: Change order of the rows in descending order with respect to computed numbers.
Step 6: Iterate step 1 until observing no change in step 3 and 5.
Step 7: Terminate

2.2. ALC Algorithm

ALC algorithm is one of the algorithms based on hierarchical clustering. The selected similarity coefficient and the methodology used in the clustering process play an important role for accuracy of the final clusters. In this study the "Jaccard Similarity Coefficient" is used in ALC algorithm. Calculation of the Jaccard similarity coefficient is given in Eq. (3) (M. Vargas and Real 2012):

$$S_{ij} = \frac{c}{a+b-c} \quad 0 \leq S_{ij} \leq 1 \tag{3}$$

Where Sij is the Jaccard Similarity Coefficient between two machines i and j, c is the number of processed parts in both machine i and machine j, a and b are the number of parts processed machine i and machine j, in order. Steps for ALC are as follow (Yin and Yasuda 2005):

Step 1: Calculate the similarity coefficients for all machine pairs and then create the similarity matrix.
Step 2: Group the two objects (two machines, a machine and a machine group or two machine group) with the highest similarity coefficient.
Step 3: Update the similarity coefficient matrix according to Eq. (4) where Nt is the number of machines in group t, and Nv is the number of machines in group v.

$$Stv = \frac{\Sigma i \in t \; \Sigma j \in v \; \text{Sij}}{\text{Nt} \times \text{Nv}} \tag{4}$$

Step 4: Go to step 5 if all the machines are grouped into a single machine group or predetermined number of machine groups has been obtained. Otherwise go back to step 2.
Step 5: Assign each part to the cell.

3. Application of ROC and ALC on Gym Centre

In this section, it is aimed to reduce walking distances of the athletes in the Gym centre at Gaziantep University according to the 10 programs which is used most frequently. After codification of sport implementation, ROC and ALC are array-based clustering techniques and similarity coefficient matrix constructed. After that, cells is formed. After the cell formation, drawing will be made according to the sports implements in the new cells and distance through programs will recalculated according to the new layout that obtained by ROC and ALC. The best results will be found after comparison new distances to the initial distances. Table 1 illustrates the codification of sport implements and Figure 1 demonstrates the initial matrix.

Table 1. Codification of Sport Equipment

	Sport Implementation	Code		Sport Implementation	Code		Sport Implementation	Code
1	Bosu-Leg-Raise	BOL	12	Vertical-Row-Lat-Pull-Down	VRLP	23	Preacher-Table-1	PRT1
2	Elliptical-Bike	ELB	13	Vertical-Bike1	VB1	24	Preacher-Table-	PRE
3	Elliptical-Cross-Trainer-1	ECT1	14	Vertical-Bike2	VB2	25	Preacher-Table-2	PRT2
4	Elliptical-Cross-Trainer-2	ECT2	15	Treadmill-Small-1	TRS1	26	Bench-Press	BEP
5	Shoulder-Press	SHP	16	Treadmill-Small-2	TRS2	27	Seated-Row-	SRO
6	Leg-Press	LPR	17	Treadmill-Small-3	TRS3	28	Mat1	MAT1
7	Leg-Curl	LCR	18	Treadmill-Big1	TRB1	29	Mat2	MAT2
8	Leg-Extension	LEX	19	Treadmill-Small-4	TRS4	30	Mat3	MAT3
9	Torso-Rotation	TRO	20	Treadmill-Small-5	TRS5	31	Dumbbell-Station-Large-	DSL
10	Cable-Crossover	CCR	21	Treadmill-Small-6	TRS6	32	Dumbbell-Station-Vertical	DSV
11	Shuttle-Equipment	SHE	22	Treadmill-Big2	TRB2	33	Dumbbell-Station-Big	DSB

After generating initial matrix and codification of sport implements, walking distance from one equipment to following equipment is created with respect to each of the 10 programs. Walking distance diagram for each program is presented in Figure 2. Also, design of the current layout is illustrated in Figure 3.

PROGRAM	Equipment																																
	BOL	ELB	ECT1	ECT2	SHP	LPR	LCR	LEX	TRO	CCR	SHE	VRLP	VB1	VB2	TRS1	TRS2	TRS3	TRB1	TRS4	TRS5	TRS6	TRB2	PRT1	PRE	PRT2	BEP	SRO	MAT1	MAT2	MAT3	DSL	DSV	DSB
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1															
2	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1	1	1	1	1	1							
3	1	1	1	1	1	1	1	1	1	1	1								1	1													
4	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1																
5	1	1	1	1	1	1	1	1					1	1				1	1		1						1	1	1				
6	1	1	1	1	1	1	1	1					1					1	1		1						1	1	1				
7	1	1							1							1	1			1		1					1				1	1	1
8	1		1	1	1	1	1	1	1	1	1			1							1	1	1				1				1		1
9	1								1	1	1		1	1							1	1	1				1				1	1	1
10		1							1					1	1	1		1	1					1			1			1	1	1	

Fig. 1. Initial matrix

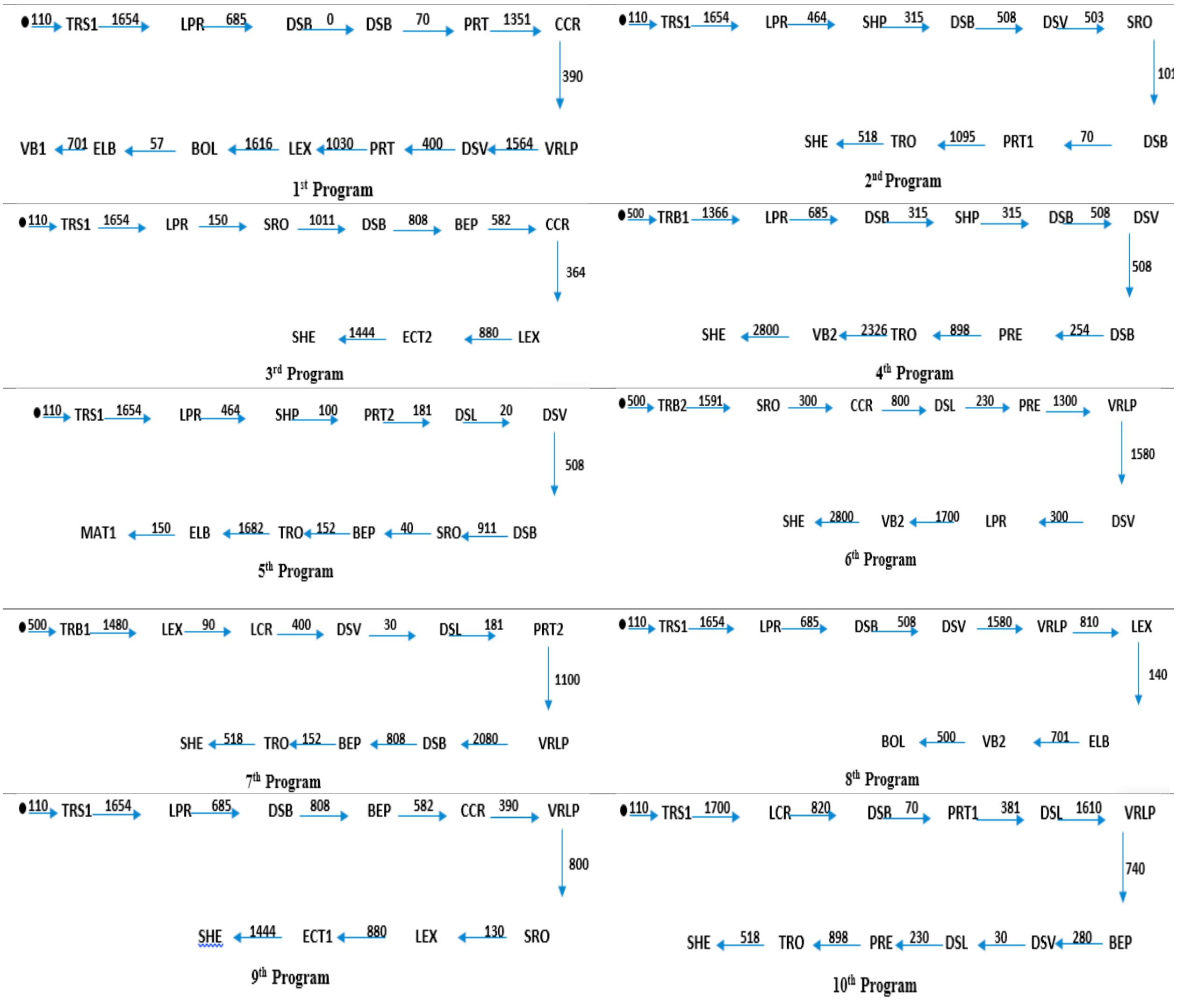

Fig. 2. Walking distance for each program

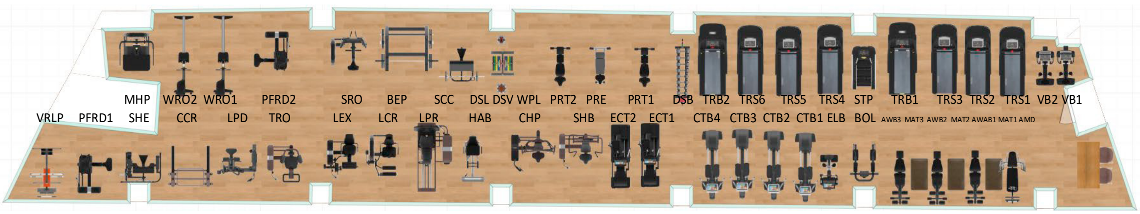

Fig. 3. Current layout of GYM centre

4. Results And Discussion

In this study, cell formation was implemented to a Gym centre. The cells were created according to two methods that are ROC and ALC. In the ROC method to find the best design of cells ROC's steps were followed. Firstly, weights were assigned for each column of the initial matrix starting from the rightmost column. And after that the column weights were summed. Next step is sorting rows by top down and after sorting weights assigned for each row of 1st iteration from the rightmost row. Then the row's weights were summed. After new matrix obtained from last steps, the columns sorted from left to right. These steps were repeated and number of iterations was created until the result came same as the previous iteration. And when the result is obtained the operation is terminated and the best solution is achieved according to the ROC algorithm which is shown in Figure 4.

		DSB	LPR	TRS1	TRS2	TRS3	TRS4	TRS5	TRS6	DSV	PRT1	PRT2	ELB	LEX	VRLP	VB1	VB2	BOL	CCR	SRO	SHP	BEP	TRO	DSL	MAT1	MAT2	MAT3	SHE	ECT1	ECT2	PRE	TRB1	TRB2	LCR	
		2^32	2^31	2^30	2^29	2^28	2^27	2^26	2^25	2^24	2^23	2^22	2^21	2^20	2^19	2^18	2^17	2^16	2^15	2^14	2^13	2^12	2^11	2^10	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
1	2^9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																8589901824
5	2^8	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1	1	1	1	1	1								8587870080
2	2^7	1	1	1	1	1	1	1	1	1	1	1								1	1														8585764864
8	2^6	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1																	8577286144
9	2^5	1	1	1	1	1	1	1	1					1	1				1	1		1						1	1	1					8558006384
3	2^4	1	1	1	1	1	1	1	1					1					1	1		1						1	1	1					8557482096
4	2^3	1	1							1							1	1			1		1					1				1	1	1	6459631694
10	2^2	1		1	1	1	1	1	1	1	1	1			1							1	1	1				1				1		1	6438788169
7	2^1	1								1	1	1		1	1							1	1	1				1				1	1	1	4325907527
6	2^0		1							1					1	1	1		1	1					1			1			1	1	1		2165228622
		1022	1017	1012	1012	1012	1012	1012	1012	975	902	902	832	626	615	585	585	576	561	433	392	310	270	263	256	256	256	63	48	48	13	11	11	6	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	

Fig. 4. ROC results after 5th iterations

After getting the ROC algorithm's result, the alternative options were made for creating cells and the following Figure 5 shows the alternative cells within squares. But, to obtain the best design for cells Γ was calculated according to the following formula:

$$\Gamma = \frac{1 - \dfrac{\text{Number of parts out of cells}}{\text{Total number of operations}}}{1 + \dfrac{\text{Total number of blanks in cells}}{\text{Total number of operations}}} \tag{5}$$

	DSB	LPR	TRS1	TRS2	TRS3	TRS4	TRS5	TRS6	DSV	PRT1	PRT2	ELB	BOL	VRLP	VB1	VB2	LEX	CCR	SRO	SHP	BEP	TRO	DSL	MAT1	MAT2	MAT3	SHE	ECT1	ECT2	PRE	TRB1	TRB2	LCR
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1															
5	1	1	1	1	1	1	1	1	1	1	1	1							1	1	1	1	1	1	1	1							
2	1	1	1	1	1	1	1	1	1	1	1								1	1													
8	1	1	1	1	1	1	1	1	1			1	1	1	1	1	1																
9	1	1	1	1	1	1	1	1						1			1	1	1		1						1	1	1				
3	1	1	1	1	1	1	1	1									1	1	1		1						1	1	1				
4	1	1							1						1	1				1		1					1			1	1	1	
10	1		1	1	1	1	1	1	1	1	1			1							1	1	1				1			1			1
7	1								1	1	1			1			1				1	1	1				1				1	1	1
6		1							1					1	1	1		1	1				1				1			1	1	1	

Fig. 5. New solution by application of Eq. (5)

As a result, the highest value obtained with Eq. (5) is 0.60 for cells which are in Figure 5 and sports implements placed to these seven cells according to this result. The Table 2 shows sport implements that assigned to cells.

Table 2. New solution by application of Eq. (5)

Cells	Sport Implements	Programs
1	DSB, LPR, TRS1, TRS2, TRS3, TRS4, TRS5 TRS6, DSV, PRT2, ELB, BOL	P1, P2, P3, P4, P5, P7, P8, P9, P10
2	VRLP, VB1, VB2, LEX	P3, P4, P6, P7, P8, P9, P10
3	CCR, SRO, SHP	P2, P3, P5, P8, P9
4	BEP, TRO, DSL	P3, P4, P6, P7, P9, P10
5	MAT1, MAT2, MAT3	P5
6	SHE, ECT1, ECT2	P3, P9
7	PRE, TRB1, TRB2, LCR	P4, P6, P7, P10

The ALC algorithm is the other method used to design the cells. In the ALC algorithm similarity coefficients between sports implements were founded to each sport implement separately by applying Eq. (3). And the matrix that obtained after founding similarity coefficients are shown in the Figure 6.

Equipment	Equipment																																
	BOL	ELB	ECT1	ECT2	SHP	LPR	LCR	LEX	TRO	CCR	SHE	VRLP	VB1	VB2	TRS1	TRS2	TRS3	TRB1	TRS4	TRS5	TRS6	TRB2	PRT1	PRE	PRT2	BEP	SRO	MAT1	MAT2	MAT3	DSL	DSV	DSB
BOL		0.67	0	0	0	0.25	0	0.4	0	0.2	0	0.33	0.5	0.5	0.29	0.29	0.29	0	0.29	0.29	0.29	0	0.17	0	0.17	0	0	0	0	0	0	0.25	0.22
ELB	0.67		0	0	0.2	0.38	0	0.33	0.17	0.17	0	0.29	0.4	0.4	0.43	0.43	0.43	0	0.43	0.43	0.43	0	0.33	0	0.33	0.14	0.14	0.33	0.33	0.33	0.17	0.38	0.33
ECT1	0	0		1	0	0.25	0	0.4	0	0.5	0.33	0.14	0	0	0.29	0.29	0.29	0	0.29	0.29	0.29	0	0	0	0	0.4	0.4	0	0	0	0	0	0.22
ECT2	0	0	1		0	0.25	0	0.4	0	0.5	0.33	0.14	0	0	0.29	0.29	0.29	0	0.29	0.29	0.29	0	0	0	0	0.4	0.4	0	0	0	0	0	0.22
SHP	0	0.2	0	0		0.38	0	0	0.4	0	0.13	0	0.17	0.17	0.25	0.25	0.25	0.2	0.25	0.25	0.25	0.2	0.33	0.2	0.33	0.14	0.33	0.33	0.33	0.33	0.17	0.38	0.33
LPR	0.25	0.38	0.25	0.25	0.38		0	0.44	0.2	0.5	0.4	0.4	0.5	0.5	0.67	0.67	0.67	0.22	0.67	0.67	0.67	0.22	0.3	0.22	0.3	0.3	0.63	0.13	0.13	0.13	0.2	0.6	0.7
LCR	0	0	0	0	0	0		0.17	0.5	0	0.33	0.33	0	0	0.13	0.13	0.13	0.25	0.13	0.13	0.13	0.25	0.4	0.25	0.4	0.4	0	0	0	0	0.5	0.25	0.22
LEX	0.4	0.33	0.4	0.4	0	0.44	0.17		0.13	0.5	0.38	0.57	0.29	0.29	0.5	0.5	0.5	0.14	0.5	0.5	0.5	0.14	0.25	0	0.25	0.43	0.25	0	0	0	0.13	0.3	0.56
TRO	0	0.17	0	0	0.4	0.2	0.5	0.13		0	0.43	0.25	0.14	0.14	0.22	0.22	0.22	0.4	0.22	0.22	0.22	0.4	0.5	0.4	0.5	0.5	0.13	0.25	0.25	0.25	0.6	0.5	0.44
CCR	0.2	0.17	0.5	0.5	0	0.5	0	0.5	0		0.43	0.43	0.33	0.33	0.38	0.38	0.38	0.17	0.38	0.38	0.38	0.17	0.13	0.17	0.13	0.29	0.5	0	0	0	0.14	0.2	0.3
SHE	0	0	0.33	0.33	0.13	0.4	0.33	0.38	0.43	0.43		0.5	0.25	0.25	0.3	0.3	0.3	0.5	0.3	0.3	0.3	0.5	0.22	0.5	0.22	0.57	0.38	0	0	0	0.43	0.4	0.5
VRLP	0.33	0.29	0.14	0.14	0	0.4	0.33	0.57	0.25	0.43	0.5		0.43	0.43	0.44	0.44	0.44	0.29	0.44	0.44	0.44	0.29	0.38	0.29	0.38	0.38	0.22	0	0	0	0.43	0.56	0.5
VB1	0.5	0.4	0	0	0.17	0.5	0	0.29	0.14	0.33	0.25	0.43		1	0.22	0.22	0.22	0.4	0.22	0.22	0.22	0.4	0.13	0.4	0.13	0	0	0	0	0	0	0.5	0.3
VB2	0.5	0.4	0	0	0.17	0.5	0	0.29	0.14	0.33	0.25	0.43	1		0.22	0.22	0.22	0.4	0.22	0.22	0.22	0.4	0.13	0.4	0.13	0	0	0	0	0	0	0.5	0.3
TRS1	0.29	0.43	0.29	0.29	0.25	0.67	0.13	0.5	0.22	0.38	0.3	0.44	0.22	0.22		1	1	0	1	1	1	0	0.5	0.11	0.5	0.5	0.5	0.14	0.14	0.14	0.22	0.5	0.78
TRS2	0.29	0.43	0.29	0.29	0.25	0.67	0.13	0.5	0.22	0.38	0.3	0.44	0.22	0.22	1		1	0	1	1	1	0	0.5	0.11	0.5	0.5	0.5	0.14	0.14	0.14	0.22	0.5	0.78
TRS3	0.29	0.43	0.29	0.29	0.25	0.67	0.13	0.5	0.22	0.38	0.3	0.44	0.22	0.22	1	1		0	1	1	1	0	0.5	0.11	0.5	0.5	0.5	0.14	0.14	0.14	0.22	0.5	0.78
TRB1	0	0	0	0	0.2	0.22	0.25	0.14	0.4	0.17	0.5	0.29	0.4	0.4	0	0	0		0	0	0	1	0.14	0.5	0.14	0.14	0.14	0	0	0	0.4	0.38	0.2
TRS4	0.29	0.43	0.29	0.29	0.25	0.67	0.13	0.5	0.22	0.38	0.3	0.44	0.22	0.22	1	1	1	0		1	1	0	0.5	0.11	0.5	0.5	0.5	0.14	0.14	0.14	0.22	0.5	0.78
TRS5	0.29	0.43	0.29	0.29	0.25	0.67	0.13	0.5	0.22	0.38	0.3	0.44	0.22	0.22	1	1	1	0	1		1	0	0.5	0.11	0.5	0.5	0.5	0.14	0.14	0.14	0.22	0.5	0.78
TRS6	0.29	0.43	0.29	0.29	0.25	0.67	0.13	0.5	0.22	0.38	0.3	0.44	0.22	0.22	1	1	1	0	1	1		0	0.5	0.11	0.5	0.5	0.5	0.14	0.14	0.14	0.22	0.5	0.78
TRB2	0	0	0	0	0.2	0.22	0.25	0.14	0.4	0.17	0.5	0.29	0.4	0.4	0	0	0	1	0	0	0		0.14	0.5	0.14	0.14	0.14	0	0	0	0.4	0.38	0.2
PRT1	0.17	0.33	0	0	0.33	0.3	0.4	0.25	0.5	0.13	0.22	0.38	0.13	0.13	0.5	0.5	0.5	0.14	0.5	0.5	0.5	0.14		0.14	1	0.43	0.25	0.2	0.2	0.2	0.5	0.63	0.56
PRE	0	0	0	0	0.2	0.22	0.25	0	0.4	0.17	0.5	0.29	0.4	0.4	0.11	0.11	0.11	0.5	0.11	0.11	0.11	0.5	0.14		0.14	0.14	0.14	0	0	0	0.4	0.38	0.2
PRT2	0.17	0.33	0	0	0.33	0.3	0.4	0.25	0.5	0.13	0.22	0.38	0.13	0.13	0.5	0.5	0.5	0.14	0.5	0.5	0.5	0.14	1	0.14		0.43	0.25	0.2	0.2	0.2	0.5	0.63	0.56
BEP	0	0.14	0.4	0.4	0.14	0.3	0.4	0.43	0.5	0.29	0.57	0.38	0	0	0.5	0.5	0.5	0.14	0.5	0.5	0.5	0.14	0.43	0.14	0.43		0.43	0.2	0.2	0.2	0.5	0.3	0.56
SRO	0	0.14	0.4	0.4	0.33	0.63	0	0.25	0.13	0.5	0.38	0.22	0	0	0.5	0.5	0.5	0.14	0.5	0.5	0.5	0.14	0.25	0.14	0.25	0.43		0.2	0.2	0.2	0.29	0.3	0.4
MAT1	0	0.33	0	0	0.33	0.13	0	0	0.25	0	0	0	0	0	0.14	0.14	0.14	0	0.14	0.14	0.14	0	0.2	0	0.2	0.2	0.2		1	1	0.25	0.13	0.11
MAT2	0	0.33	0	0	0.33	0.13	0	0	0.25	0	0	0	0	0	0.14	0.14	0.14	0	0.14	0.14	0.14	0	0.2	0	0.2	0.2	0.2	1		1	0.25	0.13	0.11
MAT3	0	0.33	0	0	0.33	0.13	0	0	0.25	0	0	0	0	0	0.14	0.14	0.14	0	0.14	0.14	0.14	0	0.2	0	0.2	0.2	0.2	1	1		0.25	0.13	0.11
DSL	0	0.17	0	0	0.17	0.2	0.5	0.13	0.6	0.14	0.43	0.43	0	0	0.22	0.22	0.22	0.4	0.22	0.22	0.22	0.4	0.5	0.4	0.5	0.5	0.29	0.25	0.25	0.25		0.5	0.3
DSV	0.25	0.38	0	0	0.38	0.6	0.25	0.3	0.5	0.2	0.4	0.56	0.5	0.5	0.5	0.5	0.5	0.38	0.5	0.5	0.5	0.38	0.63	0.38	0.63	0.3	0.3	0.13	0.13	0.13	0.5		0.7
DSB	0.22	0.33	0.22	0.22	0.33	0.7	0.22	0.56	0.44	0.3	0.5	0.5	0.3	0.3	0.78	0.78	0.78	0.2	0.78	0.78	0.78	0.2	0.56	0.2	0.56	0.56	0.4	0.11	0.11	0.11	0.3	0.7	

Fig. 6. Jaccard Similarity Coefficient for sports implements

After the similarity coefficients calculated, the highest similarity coefficients between sports implements is taken into consideration for each sport implement. Then, sport implements are grouped in accordance with highest similarity between each other consecutively. As demonstrated in Figure 7.

BOL	ECT1	SHP	LPR	LCR	LEX	TRO	CCR	SHE	VB1	TRS1	TRB1	PRT1	PRE	SRO	MAT1	DSV	DSB
ELB	ECT2	TRO	DSB	TRO	VRLP	DSL	ECT1	BEP	VB2	TRS2	TRB2	PRT2	SHE	LPR	MAT2	DSB	TRS1
				DSL			ECT2			TRS3			TRB2		MAT3		TRS2
							LPR			TRS4							TRS3
							LEX			TRS5							TRS4
							SRO			TRS6							TRS5
																	TRS6
0.67	1	0.4	0.7	0.5	0.57	0.6	0.5	0.57	1	1	1	1	0.5	0.625	1	0.7	0.78
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R

Fig. 7. Sports implement groups

Then the other similarity coefficient equation (Eq. 3) is applied to the sports implements' groups and the similarities between these groups are founded as shown in Figure 8. To obtain the best cells' result of ALC algorithm, the sports implements' groups that have highest similarity in last matrix are grouped together as cell. And the next highest similarity of the sports implements' groups are grouped as other cell. This process is repeated until seven cells created. The following Table 3 shows sport implements that assigned to cells.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
A		0.42	0.27	0.34	0.19	0.31	0.32	0.1	0.31	0.42	0.14	0.42	0.417	0.19	0.323	0.28	0.34	0.1
B	0.42		0.35	0.43	0.25	0.39	0.4	0.13	0.39	0.5	0.17	0.5	0.5	0.25	0.406	0.33	0.43	0.13
C	0.27	0.35		0.28	0.15	0.24	0.25	0.08	0.24	0.35	0.12	0.35	0.35	0.15	0.256	0.23	0.28	0.08
D	0.34	0.43	0.28		0.2	0.32	0.33	0.1	0.32	0.43	0.14	0.43	0.425	0.2	0.331	0.28	0.35	0.11
E	0.19	0.25	0.15	0.2		0.18	0.18	0.06	0.18	0.25	0.08	0.25	0.25	0.11	0.188	0.17	0.2	0.06
F	0.31	0.39	0.24	0.32	0.18		0.29	0.09	0.29	0.39	0.13	0.39	0.393	0.18	0.299	0.26	0.32	0.1
G	0.32	0.4	0.25	0.33	0.18	0.29		0.09	0.29	0.4	0.13	0.4	0.4	0.18	0.306	0.27	0.33	0.1
H	0.1	0.13	0.08	0.1	0.06	0.09	0.09		0.09	0.13	0.04	0.13	0.125	0.06	0.094	0.08	0.1	0.03
I	0.31	0.39	0.24	0.32	0.18	0.29	0.29	0.09		0.39	0.13	0.39	0.393	0.18	0.299	0.26	0.32	0.1
J	0.42	0.5	0.35	0.43	0.25	0.39	0.4	0.13	0.39		0.17	0.5	0.5	0.25	0.406	0.33	0.43	0.13
K	0.14	0.17	0.12	0.14	0.08	0.13	0.13	0.04	0.13	0.17		0.17	0.167	0.08	0.135	0.11	0.14	0.04
L	0.42	0.5	0.35	0.43	0.25	0.39	0.4	0.13	0.39	0.5	0.17		0.5	0.25	0.406	0.33	0.43	0.13
M	0.42	0.5	0.35	0.43	0.25	0.39	0.4	0.13	0.39	0.5	0.17	0.5		0.25	0.406	0.33	0.43	0.13
N	0.19	0.25	0.15	0.2	0.11	0.18	0.18	0.06	0.18	0.25	0.08	0.25	0.25		0.188	0.17	0.2	0.06
O	0.32	0.41	0.26	0.33	0.19	0.3	0.31	0.09	0.3	0.41	0.14	0.41	0.406	0.19		0.27	0.33	0.1
P	0.28	0.33	0.23	0.28	0.17	0.26	0.27	0.08	0.26	0.33	0.11	0.33	0.333	0.17	0.271		0.28	0.08
Q	0.36	0.44	0.29	0.37	0.21	0.34	0.34	0.11	0.34	0.44	0.15	0.44	0.444	0.21	0.351	0.3		0.11
R	0.1	0.13	0.08	0.11	0.06	0.1	0.1	0.03	0.1	0.13	0.04	0.13	0.127	0.06	0.1	0.08	0.11	

Fig. 8 Second similarity coefficient matrix for sport implements

Table 3. Cells, sports implements and programs for ALC algorithm

Cells	Sport Implements	Programs
1	TRS1, TRS2, TRS3, TRS4, TRS5 TRS6	P1, P2, P3, P5, P8, P9, P10
2	DSV, DSB, LPR, SRO, PRE, CCR	P1, P2, P3, P4, P5, P6, P7, P8, P9, P10
3	LEX, VRLP, SHE, BEP	P1, P2, P3, P4, P5, P6, P8, P9, P10
4	TRB1, TRB2, PRT1, PRT2, VB1, VB2, ECT1, ECT2	P1, P2, P3, P4, P5, P6, P8, P9, P10
5	BOL, ELB	P1, P5, P8
6	TRO, DSL, SHP, LCR	P2, P4, P5, P6, P7, P10
7	MAT1, MAT2, MAT3	P5

5. Conclusion

In the aspect of adjustment of cellular manufacturing to cellular service system, Gym centre layout design is studied in this study. ROC and ALC algorithms are applied in order to find the best results in terms of minimizing distances by creating cells. The cells are formed separately, sport equipment is decided for each cell according to utilized program. The next step is to determine which method is better by comparing walking distances in the cells of sports equipment. The necessary data for distance measurements were obtained by new layout where sports implements are applied.

Table 4. Results of ALC and ROC algorithm

			Distance Table
Program	Initial(cm)	ROC(cm)	ALC(cm)
1	9628	2939	3320
2	6247	3425	4131
3	7003	3600	3421
4	10475	9116	4597
5	5972	5770	5307
6	11101	6187	5413
7	7339	7590	8591
8	6880	3943	2718
9	7483	3140	3562
10	7387	6735	8686
Total	79515	52445	49746

When the distances were measured, 34% improvement is observed in the ROC compared to the beginning, while ALC showed a 37.4% improvement. In other words, due to the more decrease in ALC, better results are obtained by ALC method. In this way, the importance of applying to a new layout in the gym has been demonstrated. 37% improvement will be achieved by only replacing existing sport implements without any cost. ALC has given better results in overall compared to ROC. It is observed that half of walking distances through athlete's programs is lower in ROC compared to ALC and the other half of distances is lower in ALC rather than ROC. In total productivity is increased by 37.44% with ALC as it is shown in Table 4. Lastly, Figures 9 and 10 show the layout after ROC and ALC applications.

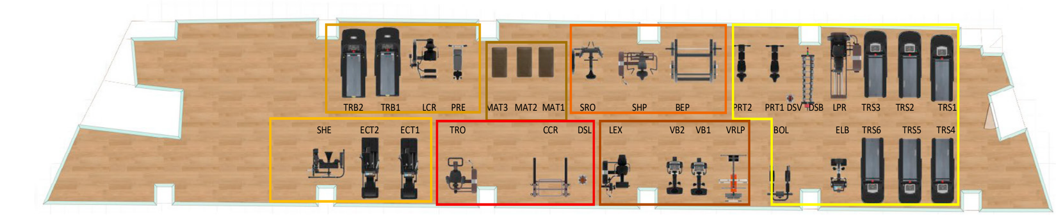

Fig. 9 Layout after ROC application

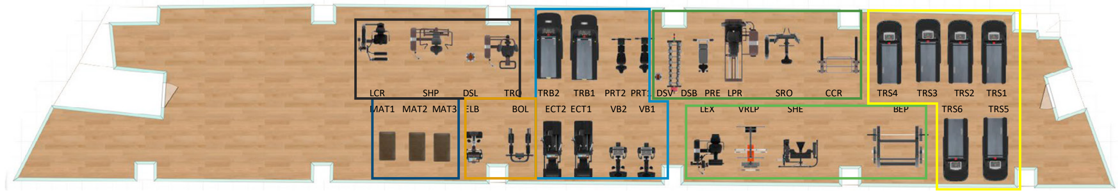

Fig. 10 Layout after ALC application

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