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A Typical Manufacturing Plant Layout Design Using CRAFT Algorithm

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Abstract

In modern technological industrial era, the typical manufacturing plant consists of a large number of diversified activities interconnected as a unit with required communication facilities. The manufacturing plant layout area consists of various activity cells such as design office, manufacturing shops, assembly and inspection departments, administration and security locations etc., The fundamental goal of facility layout problem is to minimize the material flow costs by positioning the cells within stipulated area.The orientation and spatial coordinates of each cell is specified by FLP design and the orientation of each cell may be in horizontal or vertical position.
In this paper,the manufacturing plant layouthas been designed by using Computerized Relative Allocation of Facilities Technique (CRAFT). JAVA programme has been developed to design the optimum plant layout by considering STEP file as input for developing an optimum plant layout.

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*Keywords:*Facility Layout;CRAFT Algorithm;JAVA Programming;Plant Layout

1. Introduction

Facilities location is the study of the facilityplacement on a detailed plot of land with respect tosuppliers and other facilities. Facilities design consists of the facility systems design such as structural, environmental, lighting/electrical and safety systemsetc., the layout design and the handling systems design.

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In general the manufacturing plant Layout is a systematic arrangement of facilities which are essential for production of goods or delivery of services. The performance of any job depends on entity of facilitates like machine tool, work centre, manufacturing cell, machine shop, department, warehouse etc. in a facility layout. Usually the manufacturing system faces layout problems which are related to the location of facilities in a plant.

1.1. Importance of Plant Layout

- The basic objective of the plant layout is to develop a facility layout that should be functionally better for the industry and cost savings.
- For functionally better industries the placing of necessary departments such as the operating and recovery rooms should be close together and keeping apart those departments which should not be together.
- Overall the Facility Layout includes the features of a layout which may not be immediately quantifiable, such as facilitating communication and improving staff safety.

1.2. Plant Layout Objectives

Generally the typical plant layout should possess the following objectives

- Economic demands such as investments in equipment and material handling cost are to be minimized.
- Requirement of product design and volume is to be satisfied.
- Requisite of process equipment and capacity such as minimize overall production time; maintain flexibility of arrangement and operations are to be justified.
- Different types of material handling equipment are to be facilitated in the manufacturing process.
- The quality of work life provided for employee convenience, safety and comfort; facilitate the organizational structure must be the basic priority.
- Requirement of building and site constraints such as utilizing existing space most effectively.

2. Literature Review

Traditionally, the Quadratic Assignment Problem (QAP)model has been used for layout problems. The QAP was introduced by Koopmans and Beckman in 1957for modeling the problem of locating interacting plants of equal areas[1]. The QAP has been widely applied in various applications such as urban planning, control panel layout and wiring design and also stated that the QAP is a special case of the facility layout problem due to the assumptions that all departments have equal areas and locations are fixed with a known priority [5]. The well-known Construction algorithms like CORELAP (Computerized Relationship Layout Planning) and ALDEP (Automated Layout Design Program) produce the solution *ab initio* without requiring any starting layout. Improvement algorithms, such as CRAFT and COFAD (Computerized Facilities Design), were used to start with an initial layout and try to improve it with exchanging facility. Hybrid approaches provides both construction phase and final improvement of arranging facilities.

In order to minimize material handling cost a genetic algorithm methodology was adopted for solving quadratic assignment problems [6]. An improved genetic algorithm was proposed to solve the unidirectional loop layout in order to optimize the facilities in workshop[3].

A standards-oriented form-feature extraction system was developed [4] which is known as STEP File format and it is very easy to extract the AutoCAD diagram into step file format.[2] Presented a model which is mainly projected to extract the geometric information of rotational parts from STEP file, and this information is use to recognize the features. A generalized Java code is used to extract the data from STEP file and to recognize the features.

3. CRAFT Algorithm Approach (Methodology)

Computerized Relative Allocation of Facilities Technique (CRAFT) was proposed in 1964by Buffa et al, and it is also called as computerized heuristic algorithm which takes inputs of the *load matrix* of interdepartmental flow and transaction

costs with a representation of a block layout. The existing layout or new facility or any initial arbitrary layout is considered as a block layout. Now, the algorithm computes the department allocations and estimate the cost incurred on the layout which is observed as initial travelling cost of the layout. The impact on a cost measure for two-way or three-way swapping in the location of the facilities would be computed by the governing algorithm.
The basic goal of the algorithm is to minimize total cost (TC) function, which is specified mathematically as:

$$\mathrm{TC} = \sum_{i=1}^{12}\sum_{j=1}^{12} D_{ij} \times W_{ij} \times C_{ij} \quad (1)$$

Where, D_{ij} is the distance from departments i to department j.
$W_{ij}$is the interdepartmental traffic from departments i to department j
$C_{ij}$is the handling cost between departments i and department j.

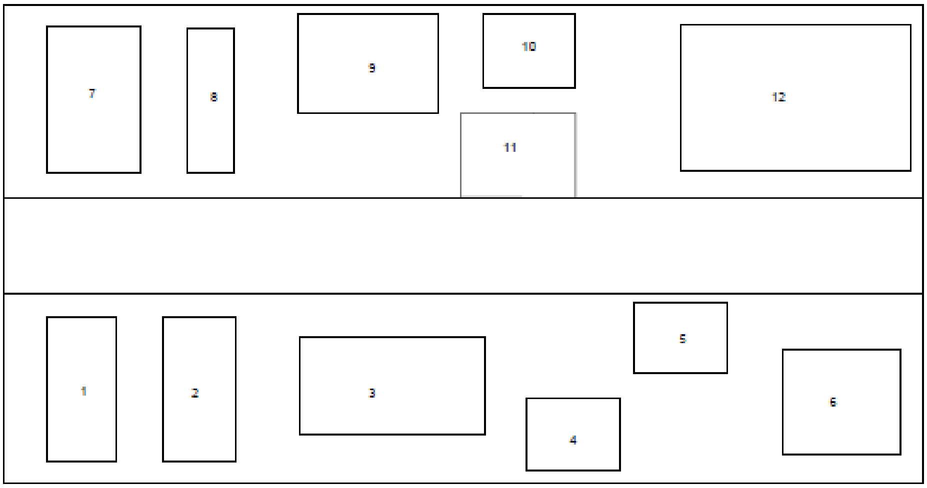

Fig.1 – Layout diagram.

3.1. Input to develop the JAVA program

Input required for applying CRAFT algorithm

- Number of departments = 12.
- Initial layout of the machine shop is taken from the AUTOCAD Diagram.
- Cost matrix = 1 rupee.
- Flow matrix (w_{ij}) of the machine shop is as given in below Table 3.

3.2. Steps in the development of layout

Step 1. Get the required information such as inputs, data required for optimization and selecting the Algorithm for optimization.
Step 2. Draw a layout diagram which acts as the initial layout for the algorithm in design software like AUTO CAD.
Step 3. Convert the line diagram into a STEP file format.
Step 4. Calculate the relation between machines in the initial layout.
Step 5. Calculate the distance between the machines in the layout using available information in STEPfile.
Step 6. Calculate the Part flow matrix, which used as input to the CRAFT Algorithm.

Step 7. The initial layout cost is calculated using Part flow matrix, distance matrix.
Step 8. The optimization of cost for initial layout is done by the replacement of the machines.
Step 9. The final result of the program is a layout with optimized cost.

Converting the input data from the auto cad file into a step file format in order to calculate the distance from each machine

```
#136=CARTESIAN_POINT ('',(15.516422487887979,14.858000423462961,0.0));
#137=CARTESIAN_POINT ('',(17.50798257909112,14.858000423462961,0.0));
#138=CARTESIAN_POINT ('',(17.50798257909112,13.316711728090851,0.0));
#139=CARTESIAN_POINT ('',(15.516422487887979,13.316711728090851,0.0));
#140=POLYLINE ('25B',(#136,#137,#138,#139,#136));
```

The distances are calculated by using the java program which takes the STEP file of the AutoCAD software as the input to the program.

```
public static void load Machines() throws FileNotFoundException, IO Exception
{
   all=new Tree Map<String,Machine>();
  RandomAccessFile rf;
   rf = new RandomAccessFile("J:\\hari\\hari prjct 2014\\hari prasad
   chittyi\\layout 2.STP","rw");
   ArrayList<String> p=new ArrayList<String>();
   String str=null;
   while(true){
   str=rf.readLine();
   if(str==null)break;
   if(str.contains("POLYLINE"))
   p.add(str);
   }
```

The above program reads the step file format into java program and the distance is calculated by the program and displayed as below table format.

Distance Matrix

Machines	Mac 1	Mac 2	Mac 3	Mac 4	Mac 5	Mac 6	Mac 7	Mac 8	Mac 9	Mac 10	Mac 11	Mac 12
1	1.0	5.99070...	7.77338...	13.8737...	19.6097...	13.6318...	5.99070...	6.81255...	9.66042...	16.6180...	15.5592...	13.5995...
2	5.99070...	1.0	7.77338...	13.8737...	19.6097...	13.6318...	5.99070...	6.81255...	9.66042...	16.6180...	15.5592...	13.5995...
3	8.69959...	8.69959...	1.0	16.5826...	22.3186...	16.3407...	8.69959...	9.52145...	12.3693...	19.3269...	18.2681...	16.3084...
4	15.6218...	15.6218...	17.4045...	1.0	29.2409...	23.2630...	15.6218...	16.4437...	19.2915...	26.2492...	25.1903...	23.2307...
5	18.6835...	18.6835...	20.5706...	27.0786...	1.0	26.3247...	20.5706...	21.3924...	24.2554...	31.1979...	30.1666...	28.1945...
6	11.4695...	11.4695...	14.5927...	22.3368...	25.0886...	1.0	16.5523...	17.3742...	20.2495...	27.1797...	26.1730...	24.1887...
7	11.8838...	11.8838...	13.5995...	19.5306...	25.5028...	19.5249...	1.0	6.81255...	7.77338...	16.6180...	10.4764...	11.7125...
8	12.7056...	12.7056...	14.4214...	20.3524...	26.3247...	20.3468...	6.81255...	1.0	8.59524...	17.4399...	11.2983...	12.5343...
9	14.5927...	14.5927...	16.3084...	22.2395...	28.2117...	22.2338...	8.69959...	9.52145...	1.0	19.3269...	13.1853...	14.4214...
10	22.5111...	22.5111...	24.2269...	30.1580...	36.1302...	30.1523...	16.6180...	17.4399...	18.4007...	1.0	21.1038...	22.3399...
11	17.5387...	17.5387...	19.2564...	25.1903...	31.1578...	25.1799...	11.7125...	12.5343...	13.5995...	22.3399...	1.0	17.5387...
12	15.5592...	15.5592...	17.2843...	23.2307...	29.1783...	23.2004...	10.4764...	11.2983...	13.5995...	21.1038...	19.2867...	1.0

Fig. 2 – Distance matrix

Now the part flow matrix is formed by the following data

Table 1 – Operation Sequence of machines

No. of Parts	Operation Sequence Of Machines
1	1→3→5→7→2→7→9→10→11
2	1→4→2→5→6→8→9→11→12
3	1→5→7→8→5→6→2→9→3→10→12
4	1→2→4→6→7→8→2→3→9→5→11→12
5	1→7→6→4→2→8→3→5→6→9→10→12

Table 2 – Part Demand for different periods

No. of Parts	Planning periods				
	1	2	3	4	5
1	10	35	90	40	55
2	30	50	25	65	20
3	45	15	40	70	15
4	70	80	5	90	85
5	85	60	70	20	30

From table 1 and table 2 we get the resultant part flow matrix which is given below which is taken as input in the java program. The part flow matrix is taken as the diagonal matrix by considering the to and from machines are same i.e., for example if machine 5 to machine 8 has a value of 15 and machine 8 to machine 5 has a value of 30 then the total value is shown in the respective column of the table below.

Table 3 – Flow matrix between different departments

Machines	1	2	3	4	5	6	7	8	9	10	11	12
1		70	10	30	45	85						
2			70	185	30	45	20	155	45			
3					95			85	115	45		
4						155						
5						160	55	45	70		70	
6							155	30	85			
7								115	10			
8									30	10		
9										85	30	
10											10	130
11												100
12												

Total travelling cost is obtained from the java program is shown in the below Fig.3. The below Figure shows the calculation of the travelling cost which is the initial layout costfor the planning period one.

Part Flow | Distance | Travelling Cost | tab4

Total Travelling Cost

Evaluate Evaluate

Total Travelling Cost 38717.824

SIno	MacNo(from)	MacNo(to)	Flow	Distance	Total Cost
1	1	2	70.0	5.990705	419.34937
2	1	3	10.0	7.773387	77.73387
3	1	4	30.0	13.873788	416.21362
4	1	5	45.0	19.609787	882.4404
5	1	6	85.0	13.631876	1158.7095
6	2	3	70.0	7.773387	544.1371
7	2	4	185.0	13.873788	2566.651
8	2	5	30.0	19.609787	588.2936
9	2	6	45.0	13.631876	613.43445
10	2	7	20.0	5.990705	119.8141
11	2	8	155.0	6.812559	1055.9467
12	2	9	45.0	9.660425	434.71915
13	3	5	95.0	22.31868	2120.2747
14	3	8	85.0	9.521451	809.32336
15	3	9	115.0	12.369317	1422.4714
16	3	10	45.0	19.326979	869.71405

Fig. 3 – Travelling cost of initial layout.

4. Results

The following results are obtained from the java program where the part flow matrix is varied for different planning periods as show in the above data.

Table 4 – Result table

Periods	Initial layout cost (Rs.)	Optimal layout cost (Rs.)	% reduction in cost of the layout
1	38,717.82	17,714.95	54.56
2	35,126.12	15,279.47	56.50
3	40,805.88	16,906.27	58.56
4	40,870.40	17,037.65	58.31
5	29,100.11	11,094.09	61.84

From the above data it is observed that there is a huge reduction in the layout cost between initial and optimal layout which place a decisive role in the generation of layouts and it may also taken into consideration of the

5. Conclusions:

In this paper the layout cost is calculated by taking the distance matrix and flow matrix. The distance matrix is obtained by converting the layout diagram into STEP File format which is taken as input to java program and output is obtained as distance matrix.

The initial layout is now optimized in order to reduce the layout cost which is done by replacements of machines in a proper sequence such that the distance matrix is altering every time and due to this the layout cost is changed.

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