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Manufacturing Plant Layout Design – An Artificial Intelligence Approach

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Abstract: The paper describes a methodology based on artificial intelligence techniques to define manufacturing plant layout in a mass customization context, where large product diversity has to be managed. Different steps are proposed keeping focus on data transformations that enable to extract relevant information for the manufacturing plant layout design. The paper also describes about traditional techniques for plant layout design and how the plant layout design technique is evolved over a period of time with advent of computer systems and artificial intelligence techniques.
Keywords: Artificial Intelligence, Plant layout, mass customization, Product Family, Product Line

I. INTRODUCTION

Plant layout design refers to the configuration of departments, machines with particular emphasis on movement of materials through the system. [1]Manufacturing enterprises, all over the world are pushed to produce personalized products to meet customer's diverse and changing needs at near production prices. This is called as mass customization. Hence manufacturing facilities designed for single product line are no longer cost effective. Manufacturing facilities should be able to exhibit high level of flexibility and robustness despite significant changes in their operating environment. Artificial intelligence (AI) can bring the flexibility and efficiency needed by manufacturing companies to reconfigure quickly manufacturing facilities to adapt for changing customer requirements. Artificial Intelligence is development of computer systems which are capable of performing tasks normally requiring human intelligence such as visual perception, speech recognition, decision making and language translation. Artificial intelligence space is matured with many sophisticated decision making algorithms which can now be used to solve problems of the large scale and complexity of the conceptual layout task. In particular, intelligent systems are now in common use solving real problems including various design tasks. With advancement in Big data technology and availability of open source analytic tools, it is now possible to use artificial intelligence models (heuristics, meta heuristics, data mining and neural network) on large amount of structured and unstructured data in manufacturing systems for layout design and analysis in cost effective manner.

II. PROBLEM STATEMENT

In mass customization, Customers select the options and alternatives they prefer to specify their own products. This customization leads to large product diversity to manage as every product may be different. For manufacturing companies, it induces small sets of variable quantities of different products to manufacture. This diverse manufacturing model leads to large impact on manufacturing process and severely impact the product quality, the lead time and the cost. The manufacturing plant layout has to be designed taking into account all these characteristics. When all products are similar, manufacturing plant layouts are relatively easy to design. However, difficulties arise when products within product family are different and require some specific manufacturing operations. In a product family all final products may be different depending on set of options and alternatives selected by diversified customers. At manufacturing level, these differences may require extra manufacturing or control operations. When a manufacturing company manufactures many sets of variable quantities of different products, plat layout may be problematic to define. It is estimated that 20-50% of the cost of manufactured part is constituted by material handling. Handling is most impacted by the layout design. Thus efficient plant layout design is essential for small production costs and for higher competitiveness. Effective plant layout design can reduce these costs to 10-30%.[7]With the need to manufacture large number of products in small quantities, it is difficult for plant layout designers and production managers to optimize plant layout design quickly for new products. Hence, there is a need to use Artificial Intelligence techniques using soft computing approach to empower plant layout designers to optimize the process workflow with in plant and quickly reconfigure workflows for new products.

III. LITERATURE SURVEY

Traditionally, plant layout design was done using string diagram and Systematic layout planning. It provides basic details about the flow of material through shop floor and interrelation of various activities. It also explains about the material flow and layout design

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using string diagram. One such research explains about the planning methods and procedures for various types of production facility. The type of layout designs to be adopted and implemented during layout design and has also provided the key elements for the design. The type of flow of material and the requirement of basic process of redesign is also explained. [3]Another research focuses on the problems occurred during flexible plant layout for manufacturing companies where product demands are subject to variability. A flexible layout maintains low material handling costs despite fluctuations in the product demand levels. [3]Research was conducted to identify and improve the plant layout of Pulley making company. Objective of that research was to eliminate obstructions in material flow and this obtain maximum productivity. The present layout and the operation process of each section (i.e. Sand mold, core making, disassembly surface finishing, furnace and inspection sections) have been investigated and new layout has been redesigned.[3]Semi-heuristic optimization algorithm (CRAFT) for designing optimal plant layouts in process focused manufacturing/service facilities was discussed. The proposed algorithm relates the well-known CRAFT (Computerized Relative Allocation of Facilities Technique) with the Hungarian assignment algorithm. Being semi-heuristic search, algorithm was likely to be more efficient in terms of computer CPU engagement time as it tends to converge on the global optimum faster than traditional CRAFT. [3]

It has been noted that the computer based layout design algorithms could not replace human judgement and experience, as these algorithms do not always capture the qualitative and intelligent aspects of layout design. However, as Artificial intelligence techniques have matured, computerized generation of alternative layouts could provide efficacious support to plant layout designers by aptly addressing some of the complex problem dynamics.

IV. PROPOSED METHODOLOGY

Several tasks of a manufacturing plant layout design can be automated with artificial intelligence techniques.

A. Problem Identification

Consider a company that manufacture small quantities of many different products. The company has set of machines (M1, M2,….,Mn) and has manufacturing processes for each set of parts. Dataset can be prepared as per TABLE I that lists products, quantity of products manufactured for a time period and manufacturing processes for each product.

Table I
List of products and their manufactring processes

Product#	Qty/Week	Manufacturing Processes			
P1	2	M1	M2	M4	M7
P2	3	M4	M7	M2	M1
P3	6	M5	M3	M6	
P4	1	M6	M5	M3	M7
…	…	…	…		

This table represents for each product the quantity that is manufactured each week and manufacturing processes of each product. For example, there are 2 quantities of product P1 to be manufactured each week. The manufacturing process of individual unit of P1 requires machine M1, then M2, then M4 and finally M6. And so on for each product. From this data set, it is possible to extract much relevant information to define manufacturing plant layout. However, in real world scenario, due to large number of different data sets of products to manufacture, TABLE I may be so large that it is impossible for human being to have global view of data to detect all relevant information for plant layout. In this case, Artificial intelligence techniques may be employed which is defined as "the discovery of non-trivial, implicit, previously unknown and potentially useful and understandable patterns from large data sets.

B. Identification of Product Families

In this step, products from same set based on manufacturing processes can be grouped into a product family. Unsupervised learning techniques like Clustering can be suitable to group products based on interpretation of data pattern within the data set.
Grouping the set of products based on manufacturing processes results in following sets of products.

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Table ii
Extracted groups from data in table 1

Group 1:	Products { P1, P2, …}
Group 2:	Products { P3, P4, …}
…	…

Each group will be a potential product line. For example, Group 1 proposes a product line for the manufacturing products {P1, P2, …} which requires machines M1, M2, M4 and M7. Based on above groups, following would be valid product lines.

Table iii
Suggested product lines

Product Line 1	Machines { M1, M2,M4,M7}
Product Line 2	Machines { M3,M5,M6}
…	…

In order to localize correctly all product lines created previously next to each other, it is necessary to evaluate the circulation of products between them. Data transformation of former results is required for it. For each product, movements between the product lines must be identified and evaluated. One of the main objectives of plant layout for manufacturing is to stream line the material flow. The focus must be on minimization of handling. The movements between departments can be derived by combining TABLE I and TABLE III.

Table IV
Manufaturing process – product line to product line

`Product#	\	Manufacturing Process	
P1	2	Product Line 1	
P2	3	Product Line 2	
P3	6	Product Line 2	
P4	1	Product Line 2	Product Line 1
…	…	…	…

C. *Identification of Relevant Manufacturing Processes*

In the second step of the methodology, all machines belonging to specific product line and the product lines are situated next to each other. The objective is now to identify a relevant manufacturing processes into each product line so as to place the machines in required order.

For each product line, the manufacturing processes of each product would be as below.

Table V

	Product#	Qty/Week	Manufacturing Processes			
Product Line 1	P1	2	M1	M2	M4	M7
	P2	3	M4	M7	M2	M1
	P4	1	M7			

It is necessary to extract identical sequences in the manufacturing processes. The sequence M4-M7 as to be identified in both products P1 and P2. The sequence of manufacturing processes for each product may be represented by developing data set for each product and each department as per below TABLE VI. In the following table, each column X_Y means Machine X is the precedent of Machine Y. M_X sets that Machine X begins the manufacturing process and that X_F represents Machine X finishes the manufacturing process. The number of lines for each product is proportional to the quantity per week. Each line of table represents the manufacturing process of the product. For example, the first line of the table means that manufacturing of a product P1, begins with Machine 1 (B_1), then goes to Machine 2 (1_2), it goes from Machine 2 to Machine 4 (2_4), from Machine 4 to Machine 7 (4_7) and Machine 7 is the final machine of this manufacturing process (7_F).

Table vi
Transformed data for each product in each product line

Pro	M_	M_	M_	M_	1_2	1_4	1_7	2_1	2_4	4_2	4_7	7_2	1_F	7_F
P	1				1				1		1			1
P	1				1				1		1			1
P			1					1			1	1	1	
P			1					1			1	1	1	
P			1					1			1	1	1	
P				1										1

Association rule can be extracted from TABLE VI. Association rule determines the associations within the data. Association rule uses two metrics support and confidence that evaluate the strength of the rule. Support indicates how frequently the item set appears in the dataset. Confidence indicates how often the rule has been found to be true. Rule with high support and confidence are strong and can be considered. Suppose that the rule "4_7=1" is the strongest rule of Table 6. It means that machine M4 is most often used just before machine M7. Then it may be advantageous to consider placement of machine M4 next to machine M7 in the order of the flow and so on from the strongest rule to the weakest until all the machines are placed. This iterative data transformation finally results in layout for each product line.

D. *Classification of new Products into Appropriate Product Family*

Classification tree techniques can be used to classify new product to fall under appropriate product family. Steps C can then be performed again to regenerate the layout.

V. CONCLUSION

Proposed methodology would enable manufacturing companies on how to automate plant layout design in mass customization context using artificial intelligence techniques, from the production routing of each product. It also emphasizes on reconsidering the whole process of layout planning when new products are introduced. Manufacturing enterprises can leverage their expert systems to automate plant layout design by leveraging the proposed methodology.

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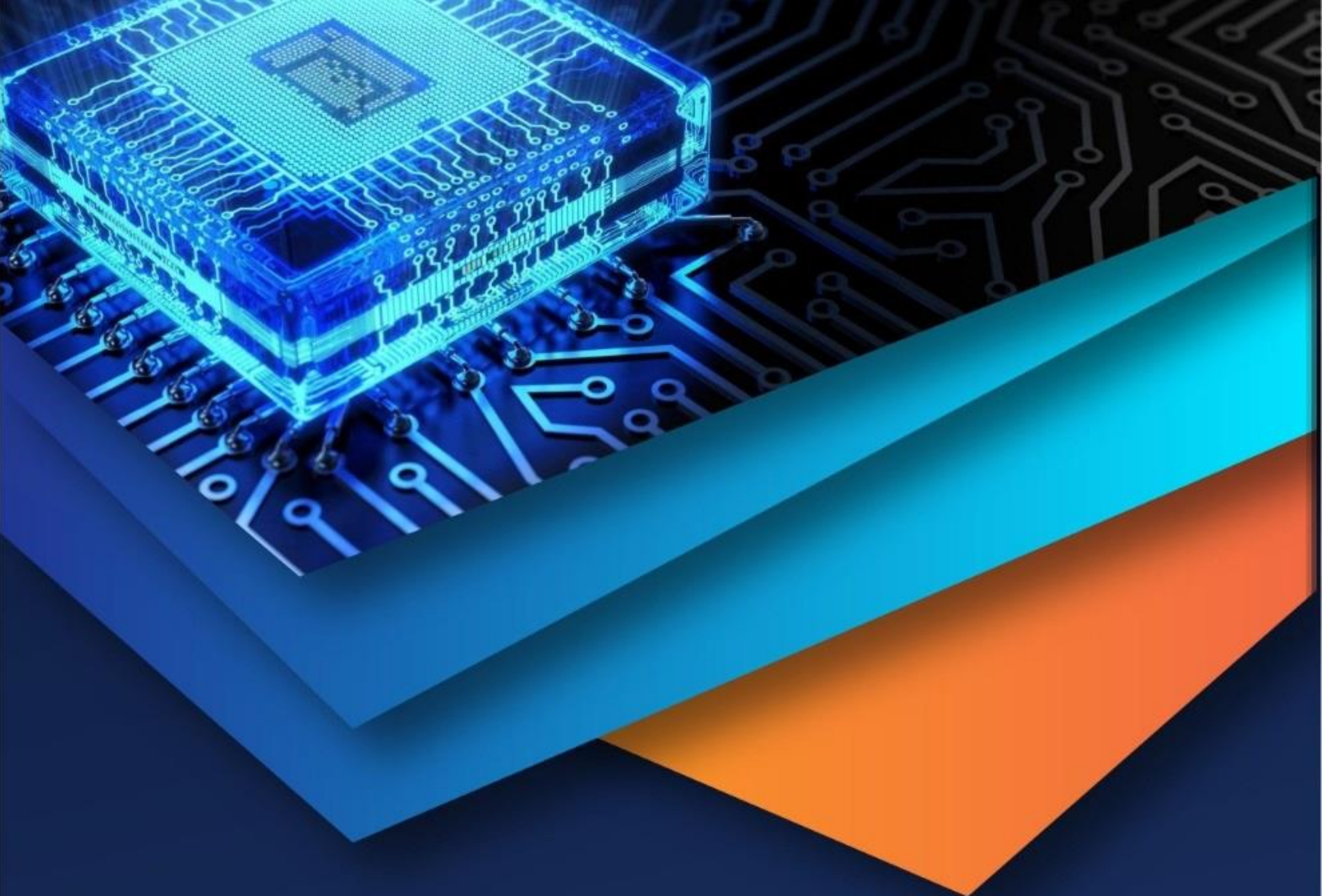

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