A PERMUTATION-BASED GENETIC ALGORITHM FOR SOLVING THE MACHINE LAYOUT OF MANUFACTURING SYSTEM

Suphatra Kritwattanakorn, Kontorn Chamniprasart, Wanwanut Boongsood*
School of Manufacturing Engineering, Suranaree University of Technology
*** E-mail: wanwanut@sut.ac.th**

ABSTRACT

In the manufacturing industry are several parameters that influence to products due to complexity of parts or components, materials, fabricating methods, etc. The popular technique used to improving manufacturing competitiveness is layout management. Therefore, this study will propose for solving the machine layout in order to minimize total distances and the assembly line in manufacturing process. Genetic algorithm is developed for permutation on Windows-based software that capable of solution general genetic algorithm within the Microsoft Excel spreadsheet and limited area is a constraint of machine layouts. The method of genetic algorithm is created initial populations by Roulette wheel selection (RWS). The new individual representation is created by crossover process from parts of population. Mutation process is changed structure of a gene in population. New population is evaluated result by objective function. The performance of the genetic algorithm is analyzed by comparing the result with general solution such as critical path method (CPM). The effective result of machine layout by genetic algorithm method is shown. The minimized total distance is considered by the key performance index of internal logistic activity in manufacturing process.

1. INTRODUCTION

In order to develop an industry sustainably, the first must be having suitable infrastructure. Layout management is one important setup which can be divided to 2 types: manufacturing layout (such as machine layout and material transportation layout) and management layout (such as department stores, the dining table in restaurant). A proper layout helps improving effectiveness of manufacturing and service. There usually have many machines or work stations in an operational area of a factory. Arranging those machines or work stations properly is essential. Minimizing material handling distance means ensuring successful internal logistics activity (Srisatja & Pupong, 2012). To have such a short distance between machines is not a stress-free task. The machines must be positioned pondering manufacturing steps in order that operations can run smooth. In some situations, there are numerous products built in the same time and each product has its own steps. Therefore, solving machine layout problem is frequently complicate. Techniques motivated by nature imitation are used for countering these complicating problems. Genetic Algorithm (GA) is one method often applied for solving machine layout (Chaudhry & Luo, 2005). GA helps generating possible solutions called population. Results calculated from each member of population are compared in order to find potential answers leading to optimization. Furthermore, iteration in GA creates new generation of population through crossover and mutation. The best answers of initial population and latter population are also equated (Pongcharoen et al., 2002). The idea of using a window based software, anyone who is interested in this can easily access to the proposed program.

2. EXPERIMENT

2.1 Machine Layout design conditions

2.1.1 Machines are rectangular in shape. The size can be determined initially but must stay constant throughout the GA process.
2.1.2 Machines can be accessed from any direction. The distance between each pair of machines is calculated from their centroids.
2.1.3 Machines are arranged from X-axis first, then new row along Y-axis.
2.1.4 Machines are arranged considering manufacturing steps.
2.1.5 Sizes of machines are smaller than working area.
2.1.6 The purpose of this study is to arrange machines not consider production time.

2.2 Genetic algorithm

Principle of GA is a stochastic search technique that imitation the process of natural selection. That can survive and be transmitted to the next generation. The remarkable result obtained by using GA process is a group of possible solutions whereas other method is individual solution (Goldberg, 1989). In a resent time, GA has been studied broadly. There are different in details based on researchers' interests, applications, and fields of engineering works. The proposed study was adapted from Simple Genetic Algorithms (SGA). It is start with an initial set of random solutions for the problem under consideration. The set of these solutions is called the population (P). The individuals of the population are called chromosomes. The results of this approach are evaluated by Fitness Function. Then, the most suitable result is transferred to the new population. Chromosome is selected into crossover process and mutation process to create next generation of possible solutions.

2.2.1 String representation

The initial population is P. In this paper, the numbers of genes in chromosome were machines as shown in Fig. 1.

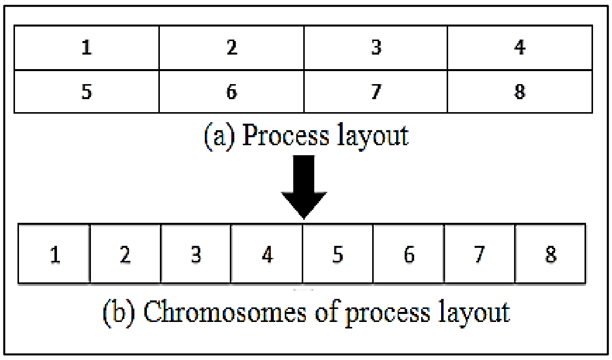

Figure.1 Chromosomes representation

2.2.2 Selection

The method of selection for reproduction used was roulette–wheel selection (Kumar, 2012). All chromosomes were within the Roulette wheel. By considering Fitness Proportionate Selection value, the chromosome having higher probability of being selected would have been chosen for reproduction process. To minimize total distances in machine layout problem, the objective function by Fitness Function can be defined as follow:

$$\text{Minimize } Z = \sum_{j=1}^{M}\sum_{i=1}^{M} f_{ij} d_{ij} \qquad (1)$$

Where Z is total distances of material handling system.

m is the number of rows

d_{ij} is the distance between machines i and j

f_{ij} is the frequency of trips between machines i and j

2.2.3 Crossover

Crossover process creates the new generation of solutions. In the proposed study, the cut section (the area between two genes in the string) and the crossover point were selected randomly. This process obtained both parents alternate between chromosomes. Program user specified crossover probability (Pc) of genes.

In this example, In this example, the cut section was four central numbers of both parents P1 = {8, 4, 2, 5} and P2 = {1, 3, 7, 6}, and the string was exchanges at the point shown in Fig. 2. (Mihajlovi, et al., 2007). New generations P1 should be lined as {2, 5, 8, 4} and P2 as {7, 6, 1, 3} as shown in Fig. 2.

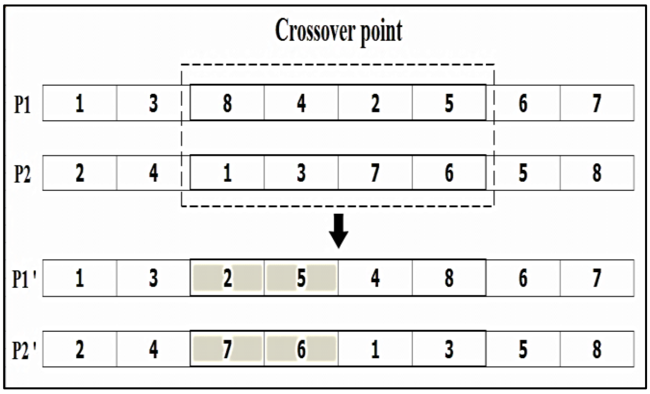

Figure.2 Crossover process

2.2.4 Mutation

Mutation process was change structure of a gene in chromosomes. It was simply selecting two genes at random and swapping their contents. The probability of mutating a single gene is usually a small number. This process prevents convergence of solution in machine layout problem as shown in Fig. 3.

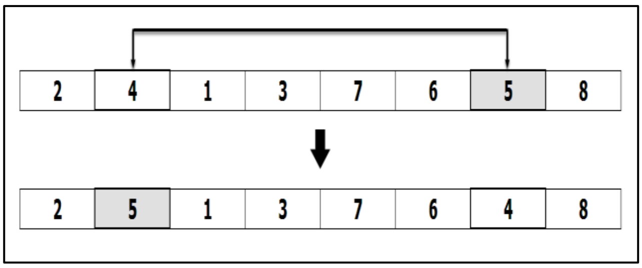

Figure.3 Mutation process

3. ANALYSIS

3.1 Mathematical Model

This paper describes a permutation-based genetic algorithm to minimize total distances in machine layout problem considering initially defined manufacturing steps and machine sizes. To minimize total distances calculated by Fitness Function (Eq. 1) of all population members. The distance between a pair of machines was determined according to the Eq. 2.

$$d_{ij} = x_{ij} + y_{ij} \qquad (2)$$

When d_{ij} is distances of machine i to j
x_{ij} is distances according to the X axis from center of machine i to j
y_{ij} is distances according to the Y axis from center of machine i to j

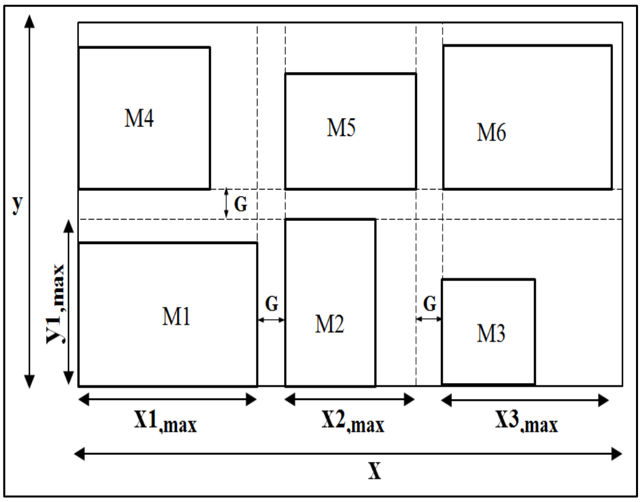

Figure.4 The arrangement of machine layout

See Fig.4, x_{ij} is summation of maximum distances according to the X axis from center of machine i to j with available space (G) that are located in the same row. Likewise, y_{ij} is the summation of maximum distances according to the Y axis by using the two formulas (Eq. 3) and (Eq. 4), respectively.

$$x_{ij} = \frac{x_{i,max}}{2} + x_{i+1,max} + \ldots + \frac{x_{j,max}}{2} + (n-1)G \qquad (3)$$

$$y_{ij} = \frac{y_{i,max}}{2} + y_{i+1,max} + \ldots + \frac{y_{j,max}}{2} + (n-1)G \qquad (4)$$

When n is number of machine i to j
G is available space between machines i to j (assume 1 m, in this example)

3.2 Example

In this case study, the proposed permutation-based genetic algorithm use to minimize total distances in Furniture production was the case. There were 3 products, 8 machines. Production routing of each product was presented in Table 1. The sizes of machines were in Table 2.

The values of the GA parameters that produce quality solutions have to be identified. This approach proposed here used initial population size (P) as 10, crossover probability (P_c) as 0.9 and mutation probability (P_m) as 0.1 (El-Baz, 2004).

Table 1. Part list and production data

Product	**Production routing**
1	A-B-C-D
2	A-E-F-G
3	A-H

Table 2. Dimensions of the machines layout

Machine layouts	Dimensions	
	Length (m)	Width (m)
A	2.00	2.00
B	1.35	1.30
C	1.35	1.25
D	1.35	1.30
E	1.22	1.25
F	1.00	1.00
G	1.22	1.25
H	1.20	1.22

The results obtained by using the proposed method were compared with initial setup, Critical Path Method (CPM), and traditional GA. The machine layout achieved by the proposed GA had shortest distance (19.62 m). The distance was same as obtained by using traditional GA but shorter in calculating time (4 sec), see Table 3. The best layout obtained by the proposed approach was shown in Fig.5.

Table 3. Comparison between the different approaches for example

Method	Successful hits	No. of trials	Time to run (s)
Current layouts	38.45	-	-
Critical Path Method (CPM)	21.88	-	-
Genetic algorithm	19.62	5000	373.8
Proposed approach	19.62	88	4.00

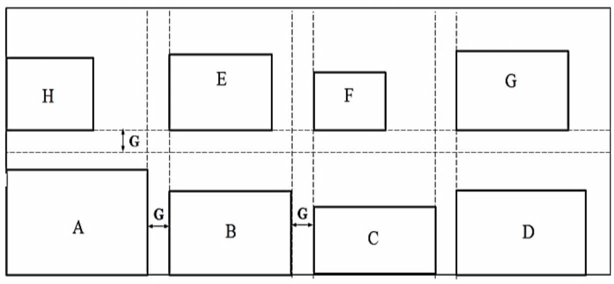

Figure.5 Best layout in the previous approaches for example

CONCLUSION

This study proposes an approach using a permutation-based genetic algorithm to minimize total distances in manufacturing system. This approach has shown better result for machine layout problem than other approaches including CPM and traditional GA.

Moreover, visual basic for applications (VBA) can be applied to calculation in Microsoft Excel spreadsheet that resulted in easy to understand and apply to other problems in the same field.

.

REFERENCES

Chaudhry, s., and Luo. w., Application of genetic algorithms in production and operations management, *international journal of production research*, Vol. 43, no. 19, pp. 4083-4101, 2005.

El-Baz M. Adel, A genetic algorithm for facility layout problems of different manufacturing environments. *Computers and Industrial Engineering*, Vol. 47, pp. 233-246, 2004.

Goldberg, D., *Genetic algorithms in search optimization and machine learning*, Addison-Wesley, New York, 1989.

Kumar, R., Blending Roulette Wheel Selection & Rank Selection in Genetic Algorithms, *Journal of Machine Learning and Computing*, Vol. 2, no. 4, pp. 365-371, 2012.

Mihajlovi. I., et al., Using genetic algorithms to resolve Facility layout problem, *Serbian Journal of Management*, Vol. 2, no. 1, pp. 35 – 46, 2007.

Pongcharoen, P., et al., Scheduling Mixed-Model Production on Multiple Assembly Lines with Shared Resources Using Genetic Algorithms, *International Journal of Production Economics*, Vol. 78, no. 3, pp. 311-322, 2002.

Vitayasak. S., and Pongcharoen. P., Designing rotatable machine layout in multiple row environment, *International Conference on Applied Operational Research in Thailand*, Bangkok, 2012.

Suphatra Kritwattanakorn
received the B.E. (2012) degree in Manufacturing Engineering from Suranaree University of Technology.

Kontorn Chamniprasart
received the B.S. (1980) degree in Mechanical Engineering from (First Class Horner) from Royal Thai Air Force Academy, Thailand, M.Sc. (1987) degree in Mechanical Engineering from University of Pittsburgh, and Ph.D. (1992) degree in Mechanical Engineering from University of Pittsburgh, USA

Wanwanut Boongsood
received the B.E. (1999) degree in Industrial Engineering from Khon Kaen University, M.E. (2006) degree in Industrial Engineering from Thammasat university, Thailand, and Ph.D. (2012) degree in Manufacturing Enginering from University of Liverpool, UK