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THE USE OF A GENETIC ALGORITHM FOR OPTIMIZING A FLEXIBLE ASSEMBLY SYSTEM

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Abstract: *Many reconfigurable conveyor-components have been developed for the construction assembly line systems. The components have different transporting paths, shapes, sizes, and etc. This paper describes a genetic algorithm to configure those reconfigurable conveyor-components forming a flexible assembly line system to meet the ever-changing production requirements. The transporting paths, shapes and sizes of reconfigurable conveyor-components are coded into binary string as chromosome to represent an assembly line layout for analysis and evaluation. The three evolutionary processes generate the layouts: selection, crossover, and mutation. The process of updating control parameters is integrated into the genetic algorithm to improve the performance and efficiency of the evolutionary processes. The reconfiguration of a flexible assembly line system to meet the requirements of minimization of the number of reconfigurable conveyor-components and the provision of alternative processes paths are discussed in details in the paper.*

Key words: *fexible assembly system, optimisation, reconfiguration.*

1. INTRODUCTION

Nowadays, the customer-driven products are very diversified. Facing of this manufacturing situation, many factories have attempted to introduce flexible assembly line systems as the strategy to produce the diversified products.

Material handling is very important, sometimes decisive for automation. Material handling costs represent a significant rate of the total production cost, being 2–3 times higher the fabrication cost, depending on the production type, the volume and the handling automation degree.

Among stocking/depositing and distributing facilities, handling function consumes the highest part of total cost.

A few handling system-types are used: linear transfers for flow automate lines, conveyors, feeding sub-systems in automate assembling, and processing center palletized transfer, industrial robots [1]. All these handling systems are integrated component parts of production systems.

Recently, many reconfigurable conveyor-components have been developed. Typical reconfigurable conveyor-components are linear conveyor, rotating conveyor, conveyor-bend, s-shape conveyor, U-shape conveyor, and lift conveyor. They have different transporting paths, shape, sizes, etc. Those reconfigurable conveyor-components can be formed into various assembly line configurations.

As the result, a number of design alternatives may exit and many possible system configurations can be formed to meet the production needs. This is very difficult to reconfigure an assembly line system among all possible configurations.

The technique of genetic algorithm is introduced in section 2.2. to overcome the difficulty of the reconfiguration of a flexible assembly line system.

1.1. Reconfigurable conveyor-components

Material handling equipment are component parts of manufacturing and assembling composing systems. These sub-systems have to have an adequate configuration to each practical application. That's why a handling system configuration (project) depends on: typological diversity of the manufacturing task, handled item-type, handled product quantity, displacement distances, and deserved manufacturing system type.

Configuration, location plan of flexible assembling systems have an important influence on the handling system, which may be totally or partly new or existing. Imposing an existing location plan limits, by the imposed restrictions, the choice / design of the best solution for the handling system. Designing a new location plan allows optimization of material flow. Different layout-types have influence in choosing handling sub-systems. Thus, the layout for a production flow includes: designing one or tow – three similar standard types; serial / large-scale production imposes the use of discontinuous conveyor-type handling sub-systems and special construction step-by-step conveyors, used on fixed routes. For eliminating blockage times, long-term storage places, located along the flow line, are required.

Typical conveyor-components are widely used to transport work-parts in an assembly line system. Linear conveyor is used for transporting the work-parts in linear direction. The length and speed of the conveyor usually can be adjusted. Rotating conveyor is mainly used to change the moving direction of work-parts. It can lift and rotate work-parts to different altitude and different orientation [5]. Conveyor-bend is used to change the moving directions of work-parts. The bend always consists of rollers or wheels, in general, with standard angles of 30°, 45°, 60°, and 90°. S-shape, Y-shape, and U-shape conveyors always consist of wheels and rollers, which are designed to flex side ways, to expand and contract for specific routing. Y-shape conveyor is widely used in a mixed-model assembly line system. U-shape conveyor usually appears in a closed loop assembly line system. Lift conveyor is designed for three-dimensional conveyor system to transport the work-parts at different levels.

2. RECONFIGURATION OF FELEXIBLE ASSEMBLY LINE SYSTEM

Manufacturing system design involves a number of interrelated subjects, e.g., tooling strategy, material-handling system, system size, process flow configuration, flexibility needed for future engineering changes or capacity adjustment and space strategy (Fig. 1). Manufacturing process design is critical area. Material handling is another area that deserves intensive study. Although this function does not add value to the product, it facilitates production process flow. The right kind of parts should be delivered in the right quantity to the right place at the right time in the right manner.

2.1. Information required for system reconfiguration

The major function of a flexible assembly line system (FALS) is to assemble a number of work-parts into a product. The information required for the reconfiguration of a flexible assembly line system can be categorized in three aspects: manufacturing data, controls, and constraints as shown in Fig. 2.

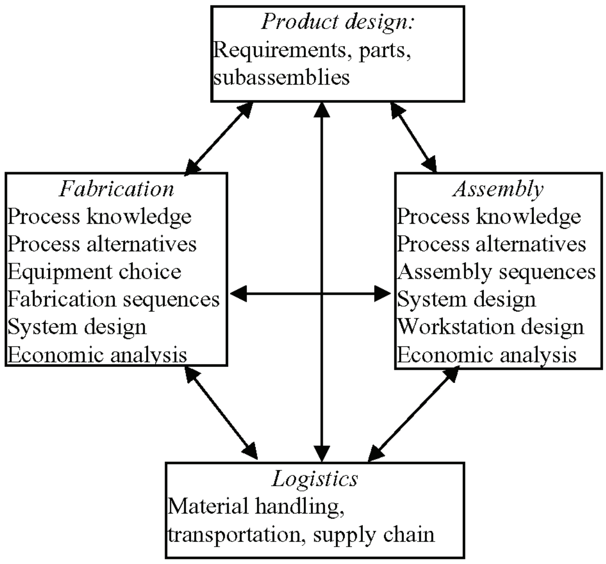

Fig. 1. Connections between product design, fabrication, assembly and logistic system.

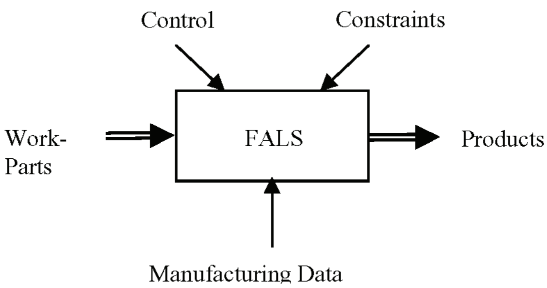

Fig. 2. The required information for the configuration of a flexible assembly line system.

Manufacturing data provide the information that directly concern with the overall assembly process such as:

- the number of assembly workstations;
- the location of the assembly workstations, loading and unloading stations;
- the processing time of each workstation;
- the size of the reconfigurable conveyor-components;
- production volume that determines the throughput of an assembly line;
- production lead-time that determines the total amount of time for assembly.

The controls provide the information that directly controls the movement of a work-part such as:

- the assembly processing sequence;
- the speed and the transporting direction of the work-part;
- the required orientation of the work-part for assembly;
- the position of the work-part assembling operation taking place.

Constraints specify the conditions of being limited for the design of an assembly line such as:

- the space restriction;
- the restriction of the assembly equipments;
- the restriction of the conveyor-components.

Currently, a number using knowledge-based system (KBS) technique for reconfiguring assembly line systems have been developed. In [5] is integrated knowledge-based system with computer-aided design (CAD) to develop a computer-aided configuration design method for redesigning assemblies of machine tool; [5] developed knowledge Petri net approach for the design of automation assembly system and developed a knowledge-based system to make flexible assembly systems to be more intelligent meeting the defined needs and the unforeseeable needs for the given recourse. KBS technique is based on the collected knowledge and expert's experience to search a possible layout. It may generate poor results due to utilization of incorrect knowledge and bad experience. This technique lacks ability in dealing with very complex problems, because KBS rely heavily on past experience. The required information may not be available and difficult to be obtained.

Genetic algorithm (GA) is well suited to tackle complex reconfiguration problems, because GA uses information-randomized (genes) exchange to exploit widely available information to tackle different design problems.

The major advantage of genetic algorithm is able to simultaneously provide solutions of satisfying different design objectives [4].

2.2. Genetic algorithm

Genetic algorithm is a search algorithm using principles of natural evolution. It simulates the evolution of a population of individual based on the rule of the survival of the fittest for the given environment. The pool of chromosomes forming the actual population contains varying genetic material.

Selection, crossover, and mutation are major genetic operators. They work selecting pairs of solutions from that population and combining them to produce new solutions. Messy genetic algorithm (MGA), which was introduced by Goldberg *et al.* [4] and works different from classical genetic algorithm (GA). MGA works with string of flexible length in which genes can be arranged in any order. The flexible length of MGA could provide the encoding of the diversified properties of the solution to design an assembly line system.

As an example, linear, rotating, and conveyors have been selected for the construction of a two-dimensional assembly line system.

Three-assembly workstation (WS1, WS2 and WS3), loading (LS) and unloading stations (US) have been positioned as shown in Fig. 3.

The process sequence of the workstations is WS1 > > WS2 > WS3. All processing workstations, loading and unloading stations are in fixed positions. The size and the processing time of each workstation are equal and the length of each linear conveyor is also equal.

Table 1 lists the required information of the manufacturing data, control and constraints for the Fig. 3.

Table 1

Required information for the reconfiguration of a flexible assembly line system

Manufacturing data	Contents
Number of assembly workstation (WS)	3
Locations of the three WS	As shown in Fig. 3
Locations of the LS and US	As shown in Fig. 3
Processing time of WS	8 minutes (min)
Length of the linear conveyor	3,2 m
Production Volume	6000 units
Time allowed for production	800 hours
Controls	**Contents**
Transporting time of rotating conveyor	3 s
Transporting time of linear conveyor	0,2 m/s
Transporting time of conveyor bend	0,2 m/s
The position of a work-part for assembling	As long as the work-part passes closely near to one side of the WS
Orientation of a work-part for assembling	All orientation
Constraints	**Contents**
Size of the assembly plant	Min_x = 50 Min_y = 50 Max_x = 400 Max_y = 400
Restriction of joining the comveyor-components	Tow rotating conveyors cannot be joined together. All conveyors move in one direction during assembly.

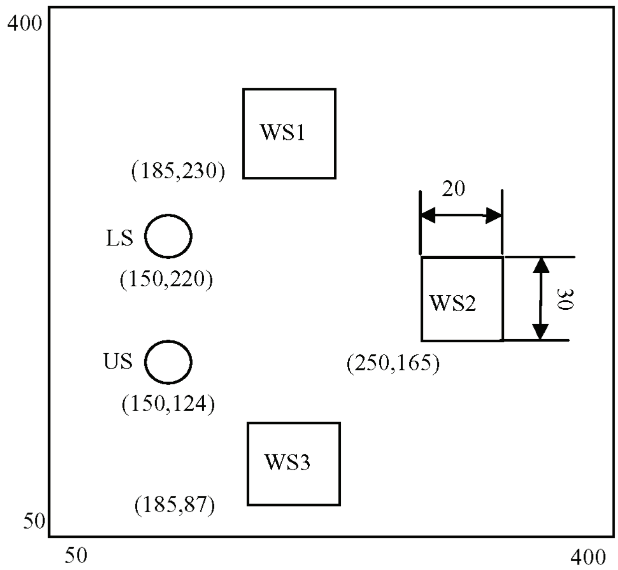

Fig. 3. The positions of assembly workstations, loading and unloading stations.

2.2.1. Messy coding representation

Messy genetic algorithm works with strings of flexible length in which genes are ordered randomly. Each gene is build by a pair of binary sets.

First set is control gene that specifies the meaning of the gene (Table 2).

Second set is performance gene that represents the executive value of the control gene. Genes are joined together to from a string of value as a chromosome (candidate layout) for evolution.

Considering the given example, the linear, rotating, and bend conveyors are joined together in the from of chromosomes.

Control gene contains two binary bits (1-2) that represent the reconfigurable conveyor-components. A tool of four different types of conveyor-components can be selected as shown in Table 3.

Performance gene (PG) contains three bits that represent the executive value of the control gene.

Control gene has the value of "00" that means none of conveyor-components to execute transporting action.

If control gene has the value "01", the rotating conveyor will perform the actions as tabulated in Table 4.

Table 2

Sequence of gene layout

Gene

Control Gene (CG)	Performance Gene (PG)
1 2	3 5

Chromosome

CG	PG	CG	PG	CG	PG	CG	PG

Table 3

Representations of control gene

Bit 1-2	Control Gene
00	None
01	Rotating Conveyor
10	Linear Conveyor
11	Conveyor- Bend

Table 4

Actions of performance gene with control gene "01"

Bit 3	Moving Direction
0	Anti-clockwise
1	Clockwise
Bit 4-5	**Rotational Angle**
00	0°
01	90°
10	180°
11	270°

If control gene contains "10", the linear conveyor will perform the actions as tabulated in Table 5. No actions execute on bit 4-5.

If control gene contains "11", the conveyor-bend will perform the actions as tabulated Table 6.

Table 5

Actions of performance gene with control gene "10"

Bit 3	Moving Direction
0	Backward
1	Forward

Table 6

Actions of performance gene with control gene "11"

Bit 3	Moving Direction
0	Anti-clockwise
1	Clockwise
Bit 4-5	**Rotational Angle**
00	300°
01	45°
10	60°
11	90°

2.2.2. Decoding

The chromosomes are decoded by binary alphabet into coordinates.

- Decoding of rotating conveyor: let x, y denote the current coordinates, x_i and y_i denote target coordinates, *rad* denotes radius of the conveyor, and θ is the rotational angle of the movement.
  The target coordinates (x_i, y_i) will be given by:

$$x_i = x + (\text{rad} \cos \theta)$$
$$y_i = y + (\text{rad} \sin \theta)\ ; \qquad (1)$$

- Decoding of linear conveyor: let x, y denote the current coordinates, Δx and Δy denote target coordinates, L denotes length of linear conveyor and φ is the current moving direction of assembly line.
  The target coordinates (x_j, y_j) will be given by:

$$x_j = \Delta x + (L \cos \varphi)$$
$$y_j = \Delta y + (L \sin \varphi); \qquad (2)$$

- Decoding of conveyor bend: let x, y denote the current coordinates, r denotes radius and s denotes the bend length, θ_b is the turning angle of the bend conveyor, and φ is the current moving direction of assembly line. The target coordinates (x_k, y_k) will be given by:

$$S = R\theta_b \ \ [\text{rad}],$$
$$x_k = x + (R \cos \varphi) + (R \cos \theta_b), \qquad (3)$$
$$y_k = y + (R \sin \varphi) + (R \sin \theta_b).$$

Those decoded chromosomes will be employed in evaluation phases to evaluate the performance of each decoded chromosome (assembly line layout).

3. DISCUSSION

The proposed genetic algorithm has been tackled two different requirements. The flexible assembly line system of fulfilling the requirements 1 is inflexible to cope with unplanned events occurred during the operation such as system component breakdown or suddenly call for product change. The operation has to stop. As the result, the production cost and time may be increased.

The flexible assembly line systems of fulfilling the requirement 2, three alternative processing paths have been generated in the layout. The alternative paths pass through the each process workstations in a given sequence.

Although the duplication of conveyor-components has increased the production cost, the flexible assembly line systems are able to deal with the change of production requirements and unplanned events occurred during assembly.

4. CONCLUSION

The proposed genetic algorithm is able to reconfigure a flexible assembly line system to meet the desired production requirements. The proposed approach offers a method for the selection amount all possible flexible assembly line system configurations of satisfying given production requirements. The advantage of the proposed genetic algorithm doesn't rely on the past experience to reconfigure the flexible assembly line system.

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