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FUZZY LOGIC APPROXIMATION FOR ASSEMBLY LINE BALANCING PROBLEM

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ABSTRACT

Assembly is a process by which subassemblies, manufactured parts and components are put together to make the final products. Assembly lines are flow-oriented production systems which are still typical in the industrial production of high quantity standardized commodities and even gain importance in low volume production of customized products.

In the most common statement of the assembly line balancing problem, a set of work elements having fixed duration times is to be assigned to a set of sequential workstations. A set of precedence relationships indicates the restrictions on the performing order of each work element. The assembly line balancing problem arises and has to be solved when an assembly line has to be configured or redesigned. It consists of distributing the total workload for manufacturing any unit of the product to be assembled among the workstations along the line.

In a production system made up of several branched manufacturing and/or assembly lines, the balancing of lines is a frequent problem. In this study, fuzzy logic methodology is used to approximate assembly line balancing problem, and the effect of three factors, as human, raw materials and technology, on assembly line balance is examined.

Keywords: Fuzzy logic, assembly lines, line balancing.

1. ASSEMBLY LINES AND LINE BALANCING

Assembly is a process by which subassemblies, manufactured parts and components are put together to make the final products [5]. Assembly lines are flow-oriented production systems which are still typical in the industrial production of high quantity standardized commodities and even gain importance in low volume production of customized products. Among the decision problems which arise in managing such systems, assembly line balancing problems are important tasks in medium-term production planning [11].

An assembly line consists of (work) stations k = 1,. . .,m arranged along a conveyor belt or a similar mechanical material handling equipment. The workpieces (jobs) are consecutively launched down the line and are moved from station to station. At each station, certain operations are repeatedly performed regarding the cycle time (maximum or average time available for each workcycle) [3, 4, 10]. An assembly line is used to assemble components into a final product. Products stay at each workstation for the cycle time, which corresponds to the time interval between successively completed units [1, 7, 8]. Assembly lines are flow oriented production systems which are still typical in the industrial production of high quantity standardized commodities and even gain importance in low volume production of customized products. Among the decision problems which arise in managing such systems, assembly line balancing problems are important tasks in medium-term production planning [4]. Assembly lines can be classified into two general groups: traditional assembly lines (with single and multi/mixed products) and U-type assembly lines (with single and multi/mixed products) [8]. Figure 1 gives a short overview of a simple assembly line structure [2].

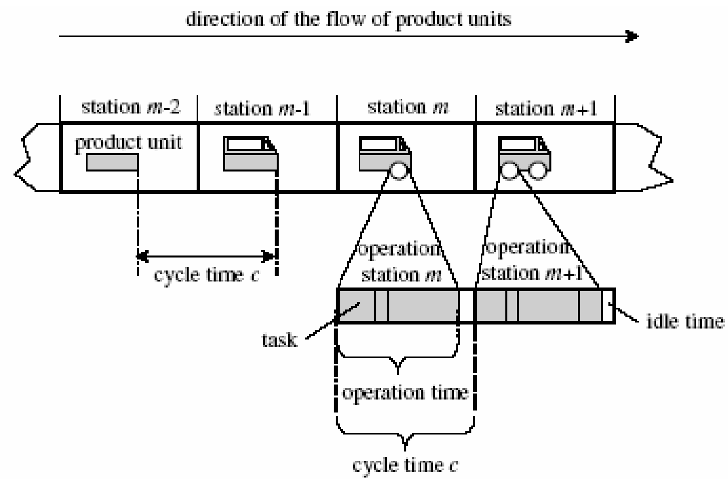

Figure 1. Structure of assembly line production [2].

The idea of line balancing was first introduced by Bryton (1954) in his graduate thesis. The first published scientific study belonged to Salveson in 1955, namely "the assembly line balancing problem". For more than 45 years, many studies were made on this subject. Duringthis period various new balancingproblem concepts such as U-type, two-sided, parallel, flexible assembly line, etc., and solution algorithms for those problems have been produced. The common thing for all these problems is usingboth the operator and the machine in the most efficient way, at the same time providing flexibility in production [1]. In the most common statement of the assembly line balancing problem, a set of work elements having fixed duration times is to be assigned to a set of sequential workstations. A set of precedence relationships indicates the restrictions on the performing order of each work element. The amount of time available at each workstation is called cycle time and it is predetermined by the desired production rate. The objective is to assign the work elements in such a manner so as to minimize the number of workstations on the assembly line, without violating the precedence constraints and without having the work element times at any station exceed the cycle time [5, 6].

The assembly line balancing problem can be explained as the requirement to assign task elements according to precedence relations and some other constraints (i.e., the compatibility between a workstation and some tasks) to each workstation on the production line in order to achieve specific objectives, such as maximizing the production rate and minimizing the number of workstations, cycle time, and slack time [7]. Balancing assembly lines is a difficult combinatorial optimization problem arising frequently in manufacturing. There are two versions of the problem. Assuming a line of identical assembly workstations and a set of tasks to be processed, the Type I simple assembly line balancing problem (SALBP-I), consists in finding an assignment of tasks to workstations such that the required number of workstations is minimized. The problem is constrained by a set of precedence relations between the tasks and by a given cycle time, which corresponds to the maximum work time available per workstation. The Type II simple assembly line balancing problem (SALBP-II) consists in allocating tasks to a given number of workstations in order to minimize the cycle time, i.e. the maximum work time of any workstation. Both versions of the problem are NP-hard [9].

2. FUZZY LOGIC APPROXIMATION FOR ASSEMBLY LINE BALANCING PROBLEM

In this study, fuzzy logic methodology is used to approximate assembly line balancing problem, and the effect of three factors, as human, raw materials and technology, on assembly line balance is examined.

There are too many factors that cause balance losses. Here, only the main three of them are taken into account: Human, raw materials and technology. It is assumed that these factors are inputs, and the output is balance loss (as percentage). This problem's structure is shown in Figure 2. These three inputs' membership degrees are arranged in the interval of [0 10] as seen from Table 1.

Table 1. The inputs's membership degrees.

Human				**Raw Materials**			**Technology**	
Bad	Average	Good	Very Good	Poor Quality	Average Quality	High Quality	Old Tech.	New Tech.
(0 0.5 1 2)	(2 2.3 3 5)	(5 6 7 7.4)	(7.4 8 9 10)	(0 2 3)	(3 4 6)	(6 8 10)	(0 2 5)	(5 7 10)

After forming the inputs, the output must be set. The output is the percentage of line balance loss. The experiences show that, the balance loss can't be more than 50%; so that the membership interval for balance loss is [0 50]. The membership degrees for output is as Table 2. Also, Figure 3 shows the membership function plot of output.

Table 2. The output's membership degrees.

Balance Loss				
Balanced	Acceptable	Average	Few	Unbalanced
(0 5 10)	(10 15 20)	(20 25 30)	(30 35 40)	(40 45 50)

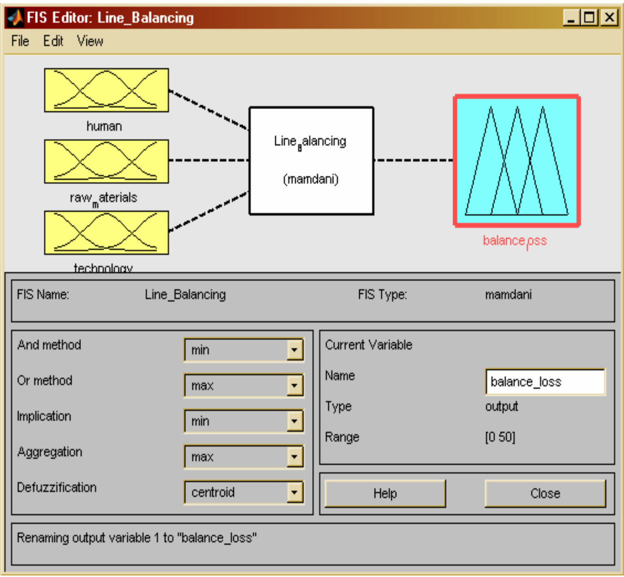

Figure 2. The line balancing problem's structure.

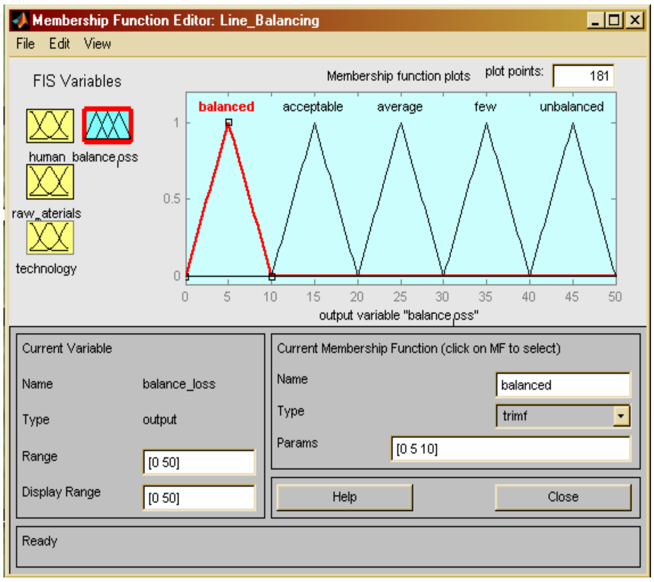

Figure 3. Membership function plot of output.

Eleven rules are determined for fuzzy approximation, i.e.;
If human is average *or* raw materials are poor quality *or* technology is old tech. *then* balance loss is few.
If human is very good *and* raw materials are high quality *then* balance loss is balanced, etc.

After using fuzzy inference system in Matlab 7.0, the line balance loss is found as 25% and the effects of human, raw materials and technology factors on line balance are determined. Under our membership degree assumptions for inputs and output, it has seen that human factor has a big effect on balance loss. Raw materials' and technology's effects on balance loss are almost the same and lower than human's. Figure 4 shows the interaction between inputs and output. Figure 5 shows the human and raw materials' effects on balance loss.

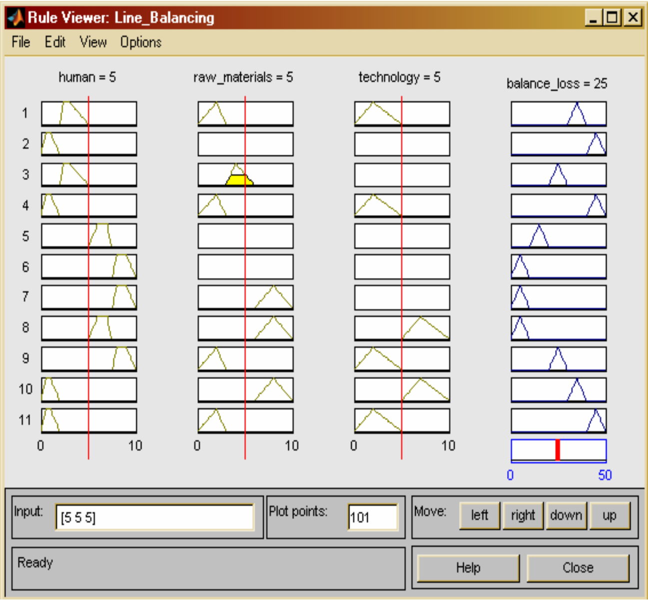

Figure 4. Intraction between inputs and output.

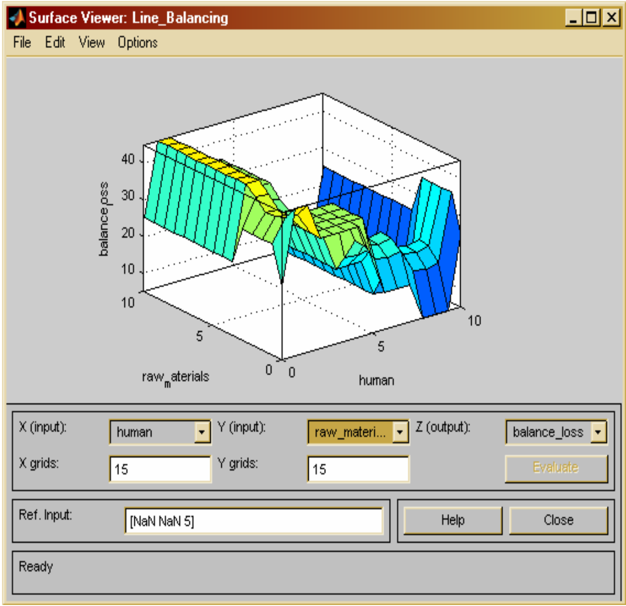

Figure 5. The human and raw materials' effects on balance loss

3. CONCLUSION

In a production system made up of several branched manufacturing and/or assembly lines, the balancing of lines is a frequent problem. In this study, fuzzy logic methodology is used to approximate assembly line balancing problem, and the effect of three factors, as human, raw materials and technology, on assembly line balance is examined.

4. REFERENCES

[1] Ağpak K., Gökçen H.: Assembly line balancing: Two resource constrained cases, Int. J. Production Economics 96, pp. 129–140, 2005,

[2] Amen M.: Cost-oriented assembly line balancing: Model formulations, solution difficulty, upper and lower bounds, European Journal of Operational Research, Vol. 168, Issue 3, pp. 747-770, 2006,

[3] Bautista J., Pereira J.: Ant algorithms for a time and space constrained assembly line balancing problem, European Journal of Operational Research, In Press, Corrected Proof, Available online 2 February 2006,

[4] Becker C., Scholl A.: A survey on problems and methods in generalized assembly line balancing, European Journal of Operational Research, Vol. 168, Issue 3, pp. 694-715, 2006,

[5] Dimitriadis G.: Assembly line balancing and group working: A heuristic procedure for workers' groups operating on the same product and workstation, Computers&Operations Research, Vol. 33, Issue 9, pp. 2757-2774, 2006,

[6] Driscoll J., Thilakawardana D.: The definition of assembly line balancing difficulty and evaluation of balance solution quality, Robotics and Computer Integrated Manufacturing 17, pp. 81-86, 2001,

[7] Gökçen H., Ağpak K.: A goal programming approach to simple U-line balancing problem, European Journal of Operational Research, Vol. 171, Issue 2, pp. 577-585, 2006,

[8] Gökçen H., Ağpak K., Benzer, R.: Balancing of parallel assembly lines, International Journal of Production Economics, In Press, Corrected Proof, Available online 14 February 2006,

[9] Lapierre S.D., Ruiz A., Soriano, P.: Balancing assembly lines with tabu search, European Journal of Operational Research, Vol. 168, Issue 3, pp. 826-837, 2006,

[10] Peeters M., Degraeve Z.: A linear programming based lower bound for the simple assembly line balancing problem, European Journal of Operational Research, Vol. 168, Issue 3, pp. 716-731, 2006,

[11] Scholl A., Becker C.: State-of-the-art exact and heuristic solution procedures for simple assembly line balancing, European Journal of Operational Research, Vol. 168, Issue 3, pp. 666-693, 2006.