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A note on 'balancing printed circuit board assembly line systems'

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In a recent paper of (Lapierre, S.D., Debargis, L. and Soumis, F., Balancing printed circuit board assembly line systems. *Int. J. Prod. Res.*, 2000, **38**, 3899–3911.), the authors considered the balancing of a PCB assembly line consisting of several pick-and-place machines. The authors claimed that, for the particular machine type they considered, the component placement time is independent of the placement sequence of the components and then concentrated on allocating component types to machines and configuring the feeders on each machine to balance the line. We show that, the placement time is actually dependent on the placement sequence and thus, it needs to be accounted for if a more accurate line balance is looked for.

1. Introduction and development

Lapierre *et al.* (2000) considered the assembly optimization and balancing of a line consisting of several pick-and-placement machines. These machines have stationary board carriers and feeder mechanism(s) located on one or both sides of the machines as illustrated in figure 1 on page 3901. The head is responsible from picking up components from feeder slots, bringing them over the PCB and performing the placement. While the head moves in one direction, the arm that it is connected to moves in the other direction so that the resulting distance measure turns out to be Chebyshev.

On page 3901, the authors said that 'In such a specialised environment, the placement sequencing of each component on the PCB does not matter: only component allocation to machines and location on the feeder impact the final assembly time.' The authors then calculated the placement time of each component type for every possible location in the feeder slots and used these numbers as an input to their model. This statement is not true as we show below.

For the pick-and-place machine they considered, as shown in Duman (1998) in detail, not only the component placement times is dependent on the feeder configuration and placement sequence, the optimum feeder configuration is dependent on the placement sequence also.

In order to place a component at location j on the PCB, the head, first should move from the previous location to the feeder slot where the tape containing the

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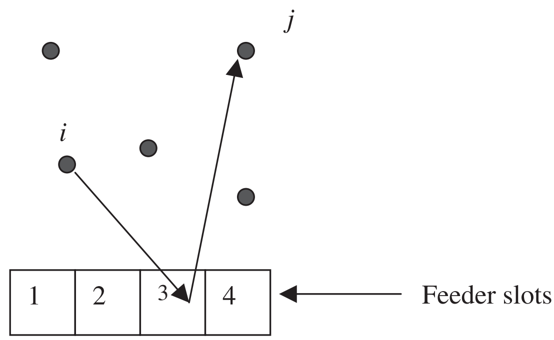

Figure 1. Illustration of the calculation of t_{ij}.

type of components to be placed at location j are situated, and then to location j. Thus, the placement time of component j is dependent on the previously placed component. Consequently, for a given feeder configuration, the placement sequencing problem can (should) be modelled as a travelling salesman problem (TSP). In the TSP formulation, t_{ij}, the time between the completion of consecutive placements at points i and j, is defined as follows:

$$t_{ij} = \max(t^1_{i,f(j)}, t^2_{i,f(j)}) + \max(t^1_{f(j),j}, t^2_{f(j),j}) \quad (1)$$

where $f(j)$ is the feeder location containing components of type j and t^1 and t^2 are x and y movement times of the head. See figure 1, where t_{ij} is the sum of the Chebyshev travel times of the two arrows shown.

On the other hand, for a given placement sequence, the feeder configuration problem can be modelled as a linear assignment problem where, c_{ij}, the cost of assigning a component type i to feeder location j is calculated as follows.

Let S_i = the ith location visited in the given TSP tour; x_j = the x coordinate of feeder location j (y coordinate is zero); $y_i = y$ coordinate of any point i.

Determine $S(i) = \{S_k$: the component at location k is of type $i\}$.

Then, c_{ij} becomes

$$c_{ij} = \sum_{k \in S(i)} \{\max\{|x_{S_{k-1}} - x_j|, y_{S_{k-1}}\} + \max\{|x_{S_k} - x_j|, y_{S_k}\}\} \quad (2)$$

Stated differently, c_{ij} is the sum of all in and out Chebyshev travel times to location j for component type i.

The calculation of c_{ij} is best illustrated in figure 2 where, there are four component types (A, B, C, D) and four feeder locations (1, 2, 3, 4). Let the placement sequence be A–B–D–C–A–B. The cost of assigning component type B to feeder location 2, is the sum of the Chebyshev travel time of the four arrows drawn. According to this illustration it is evident that c_{ij}, and consequently the feeder configuration problem, are dependent on the placement sequence.

For the class of placement machine types considered, the dependency of the placement times and the optimal feeder configuration to the placement sequence had also been pointed out by Drezner and Nof (1984) and Ball and Magazine (1988).

As a result, contrary to Lapierre *et al.* (2000), the placement sequencing does matter. Furthermore, in their model provided on page 3904, t_{ijk} (time to insert

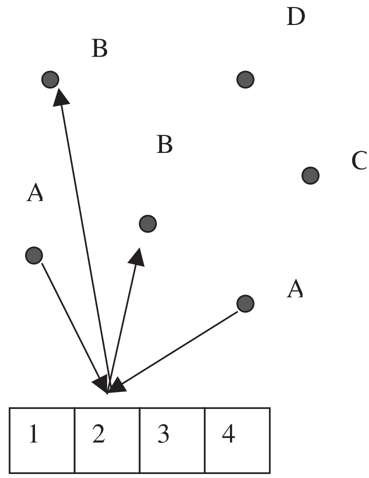

Figure 2. Illustration of the calculation of c_{ij}.

component type j when located on machine i at location k) values are taken as constant. When they become variables as we discussed above, constraint set (2) will include nonlinear terms and their model will no longer be an integer programming model. In order for their model to be valid, placement times of the components should be assumed to be constant (for a given feeder configuration) and the dependency of the feeder configuration problem to the placement sequence is ignored.

References

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