# A Hierarchical Classification Scheme for Electronics Assembly Problems

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**Abstract**

We present a hierarchical classification scheme for the problems encountered in printed circuit board (PCB) assembly. The classification is based on the number of machines (one or many) and number of boards (one or many) present in the problem. The scheme also incorporates lower level classifications presented in the literature.

## 1 Introduction

The most prevalent analytical approach to production planning problems of flexible manufacturing systems (FMSs) attempts to hierarchically decompose the problem into a number of more easily manageable subproblems. One of the main reasons for this kind of approach is that the original problem is usually too complex to be solved globally, whereas it is easier to solve each subproblem one at a time. The solution to the global problem can then be obtained by solving the subproblems successively. Naturally, this solution is not likely to be globally optimal, even if all subproblems are solved to optimality. Nonetheless, this approach is a productive and popular way to tackle hard problems, and the majority of production planning software systems utilize, in some way or another, hierarchical decomposition technique.

Traditionally, a hierarchical classification scheme for assembly problems discerns (1) *strategic level* or *long-range planning* which concerns the initial deployment and subsequent expansion of the production environments, (2) *tactical level* or *medium-range planning* which determines the allocation patterns of the system production capacity to various products so that external demands are satisfied, and (3) *operational level* or *short-range planning* which coordinates the shop floor production activities so that the higher level tactical decisions are taken into consideration [3].

This paper concentrates on tactical and operational level problems in printed circuit board (PCB) assembly. We present in the next section a novel hierarchical classification scheme for PCB assembly problems (for further details and a review of the relevant literature, see [6]).

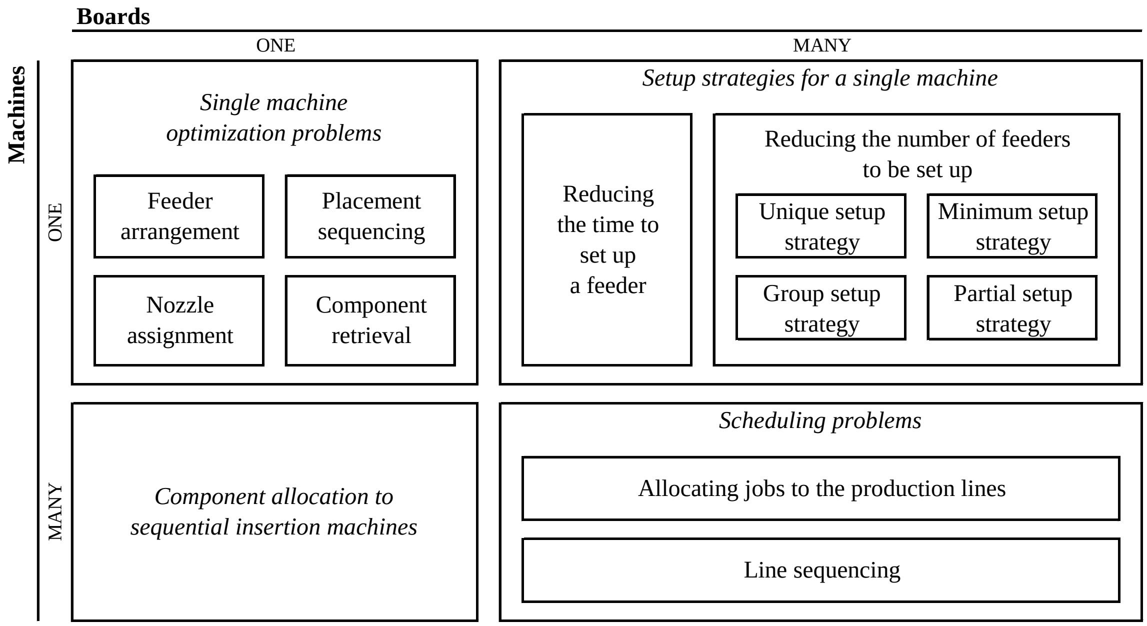


Figure 1: A hierarchical classification scheme of the PCB assembly problems

## 2 Hierarchical Classification

Generally speaking, we can classify the PCB assembly problems according to the number of different board types (one or many) and machines (one or many) present in the problem (see Figure 1). Accordingly, the four main problem classes are:

ONE PCB TYPE AND ONE MACHINE (1–1) class comprises *single machine optimization* problems, where the goal is to minimize the printing time of the machine. The class can be further divided into four subclasses [2]:

- *feeder arrangement* problem concerns assigning components to the feeder slots,
- *placement sequencing* (or insertion order) problem concerns determining the sequence in which the components are printed on the board,
- *nozzle assignment* problem concerns the tool changes for the placement head, and
- *component retrieval* problem concerns determining from which feeder slot the component is retrieved if it has been assigned to more than one slot.

MULTIPLE PCB TYPES AND ONE MACHINE (M–1) class comprises *setup strategies for single machine*. There are two approaches to reduce setup times [1]: (1) reduce the time to set up a feeder, and (2) reduce the number of feeders to be set up. In the latter case, the setup strategies can be classified as follows [4]:

- *unique setup strategy*: Consider one board at a time and specify the component–feeder assignment and the placement sequence so that the placement time is minimized. This is a common strategy when dealing with a single product and a single machine in a high-volume production environment.

- *minimum setup strategy*: Sequence the boards and determine feeder assignments to minimize the total component setup time. The idea is to change only the feeders required to assemble the next board. In general, similar product types are produced in sequence so that little changeover time incurs.
- *group setup strategy*: Form families of similar parts so that setups are incurred only between the families. Therefore, any board within a group can be produced without changing the component setup. Because the placement time for a specific board is, in general, larger than in unique setup strategy, some efficiency can be potentially lost. However, this is compensated by less frequent setup operations, which compensates the losses in machine speed especially in high-mix, low-volume production.
- *partial setup strategy*: Sequence the boards and determine a subset of the feeders on a machine that are changed when switching from one product to the next. Because the goal is to minimize makespan, the partial setup strategy resides between the unique setup strategy (where only the placement time for each individual PCB is minimized) and the minimum setup strategy (where only the changeover time of each PCB is minimized).

ONE PCB TYPE AND MULTIPLE MACHINES (1–M) class concentrates on *component allocation to sequential insertion machines*, where the usual objective is balancing the workload of the machines in the same line (usually by eliminating bottlenecks) [5].

MULTIPLE PCB TYPES AND MULTIPLE MACHINES (M–M) class or *scheduling problems* usually concentrate on

- allocating jobs to lines which includes routing, lot sizing and workload balancing between lines, and
- line sequencing.

# 3 Concluding Remarks

The most noticeable flaw in the hierarchical classification scheme is workload balancing, and, consequently, we must differentiate two kinds of balancing: We can balance the workload either among several *parallel lines* (i.e., “interline” balancing) or among machines within the *same single line* (i.e., “intraline” balancing). The former clearly belongs to the problem class (M–M), whereas the latter is an instance of the problem class (1–M). Nevertheless, this only demonstrates the usefulness of the scheme, since the approaches for achieving interline or intraline balancing are somewhat different from each other and therefore cannot be lumped together.

The main advantage of the hierarchical classification scheme is that it makes easier to recognize the problems and to find suitable and efficient approaches for solving them. In addition to theoretical interest, the scheme also provides support for practical issues. It is a natural basis for a production planning system, where optimization is done separately for each subproblem. It has provided us with good results in both designing and implementing software systems for electronics manufacturers (e.g., see [7, 8]).

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