A multiple objective grouping genetic algorithm for assembly line design

BRAHIM REKIEK,1 PIÈRE DE LIT,1 FABRICE PELLICHERO,2 THOMAS L’ÉGLISE,3 PATRICK FOUDA,1 EMANUEL FALKENAUER2 and ALAIN DELCHAMBRE1

1CAD/CAM Department, Université libre de Bruxelles, 50 av. F. D. Roosevelt, CP 165/14, B-1050 Brussels, Belgium
E-mail: brekie@ulb.ac.be
2Optimal Design (spin-off of Université libre de Bruxelles), 20 rue de l’Industrie, B-1400 Nivelles, Belgium
3Université catholique de Louvain, Department of Mechanical Engineering, place du Levant, Bât. Stevin, B-1348 Louvain-La-Neuve, Belgium

The purpose of this paper is to describe some of the main problems concerning assembly line design. The focus will be on the following steps: (1) the input data preparation, (2) the elaboration of the logical layout of the line, which consists in the distribution of operations among stations along the line and an assignment of resources to the different stations, (3) finally the mapping phase using a simulation package to check the obtained results. This work presents a new method to tackle the hybrid assembly line design, dealing with multiple objectives. The goal is to minimize the total cost of the line by integrating design (station space, cost, etc.) and operation issues (cycle time, precedence constraints, availability, etc.). This paper also presents in detail a very promising approach to solve multiple objective problems. It is a multiple objective grouping genetic algorithm hybridized with the multicriteria decision-aid method PROMETHEE II. An approach to deal with user’s preferences in design problems is also introduced. The essential concepts adopted by the method are described and its application to an industrial case study is presented.

Keywords: Assembly line design, multiple objective problems, grouping genetic algorithm, multicriteria decision-aid

1. Introduction

An assembly line is a familiar example from the realm of manufacturing. Flow lines are found in all types of industries, wherever “products” may be imagined to move along from station to station. Assembly is a process by which subassemblies and components are put together yielding the finished products. The assembled product takes shape gradually, starting with one part (usually called the base part), the remaining parts being attached at the various stations the product visits.

An assembly line is a sequence of stations, connected together by a material handling system. Each station performs one or more tasks (addition of components, inspection, etc.) on the partially finished product. Tasks are accomplished by a group of workers, machines or robots. After a lapse of time called cycle time, the conveyor moves, thus positioning each product in front of the next station in the line. The product previously at the last station is finished and leaves the line. Figure 1 illustrates our words.

The design of manufacturing systems involves the design of products, processes and plant layout before the physical construction. Among them, the design of
an efficient assembly line is a problem of considerable industrial importance. The main objective of assembly system designers is to increase the efficiency of the line by maximizing the ratio between throughput and the required costs.

Line layout problems are divided into logical and physical layout (Delchambre, 1996). The goal of the former is to assign tasks to a set of stations and to decide about the stations order along the line. The latter determines the space requirements, taking into account station dimensions, material storage, etc. In this paper the authors are more concerned with the logical line layout (LLL) of assembly lines.

The LLL is divided in the literature into assembly line balancing (ALB) and resource planning (RP) problems. The balancing, used especially for manual assembly lines (MALs) aims to balance the loads of the stations. This approach is appropriate for such systems, since the primary concern is the distribution of tasks among operators while keeping a desired production rate. The global cost of MALs is directly influenced by the number of stations. Thus, the main objective is to minimize their number.

On a so-called hybrid assembly line (HAL), tasks can be executed either manually, by robots or by hard automated equipment. In general, the operating time and cost depend on the resource used. Given a list of candidate equipment available to complete the operations, the problem is to decide which resources to use and which tasks to assign to each of them. The main objective of this RP is to minimize the total cost of the line by integrating design (station space, cost, etc.) and operation issues (cycle time, precedence constraints, availability, etc.).

A manufacturer–designer asked to design a new assembly line in a short time with a given budget and a specified capacity has to make several major decisions. The trade off between cost, reliability, imbalance between station, functionality, etc. constitutes a set of objectives to reach (Chow, 1990). Assembly line design (ALD) problems are multi-criteria ones. That is, those problems involve multiple often conflicting objectives to be met and ask for a compromise amongst them.

The remainder of this paper is organized as follows. In Section 2, a detailed description of the ALD problem is given, discussing its constraints as well as its objectives. Section 3 presents related work concerning ALD techniques. The first phase of the integrated approach which is the ‘preparation of data’ is introduced in Section 4. Section 5 is devoted to the optimization phase, while the mapping phase is presented in Section 6. Some results are given in Section 7, and conclusions are drawn in Section 8.

2. Assembly line design

2.1. Task and resource assignment problems

Generally, for a given manufacturing environment, the design goals (throughput, cycle time, etc.) and the constraints (number of stations, etc.) are defined. The problem is then partitioned into a number of linked subproblems. Since the scope of each subproblem is limited, a more complete analysis becomes possible. Results of analysis should help to reduce the number of alternatives at the subproblem level and consequently simplify the overall design problem.

The proposed method is built upon many collaborations with industrials. Its main steps can be summarized as follows (refer to Fig. 2).

- **Preparation:** The designer introduces its input data (tasks, resources, constraints, preferences, etc.).
- **Optimization:** The optimization method proposes a line architecture (station contents, their order, etc.).
- **Mapping:** The mapping allows the designer to analyze and test the results using a simulation package.

One of the most important aspects of the method is its interactivity and its iterative use to design the