Available online at www.sciencedirect.com
SCIENCE DIRECT®
Computers & Industrial Engineering 46 (2004) 141–157
computers & industrial engineering
www.elsevier.com/locate/dsw

An improved genetic heuristic to support the design of flexible manufacturing systems

Lídia Lampreia Lourenço[a,*], Margarida Vaz Pato[b]

[a]Department of Mathematics, Faculty of Sciences and Technology, New University of Lisbon, and Operations Research Centre, Faculty of Sciences, University of Lisbon, Quinta da Torre, 2829-516 Monte de Caparica, Portugal
[b]Department of Mathematics, Faculty of Economics and Business Administration, Technical University of Lisbon, and Operations Research Centre, Faculty of Sciences, University of Lisbon, Rua do Quelhas, 6, 1200-781 Lisboa, Portugal

Abstract

In industry, when flexible manufacturing systems are designed within a group technology approach, numerous decision-taking processes emerge requiring control of the multiple characteristics of the system. In this context, several grouping problems are identified within the scope of combinatorial optimisation. Such is the case of the part families with precedence constraints problem, which is defined in order to set up families where the total dissimilarity among the parts placed in the same family is minimal and precedence constraints, as well as capacity constraints arise when grouping parts. The present paper describes the use of an improved genetic heuristic to tackle this problem. It comprises a standard genetic heuristic with appropriate operators, improved through specific local search. In order to study the performance of the improved genetic approach, a special purpose constructive heuristic plus an earlier version of the genetic heuristic were implemented. CPLEX software was used from a binary linear formulation for this problem. Computational results are given from the experiment performed using test instances partly taken from the literature while others were semi-randomly generated. The improved genetic heuristic produced optimal solutions for most of the shortest dimension test instances and acted positively in relation to the constructive heuristic results, over almost all the instances. As for the CPLEX it found optimal solutions only for the small instances, besides which for the higher dimensioned instances CPLEX failed to obtain any integer solutions at all, in 10 h running time. Therefore, these experiments demonstrate that the improved genetic is a good tool to tackle high dimensioned test instances, when one does not expect an exact method to find an optimal solution in reasonable computing time.

Keywords: Flexible manufacturing systems; Part families problem; Genetic heuristics

* Corresponding author. Fax: +351-212-948-391.
E-mail addresses: lll@fct.unl.pt (L.L. Lourenço), mpato@iseg.utl.pt (M.V. Pato).

0360-8352/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cie.2004.01.001

1. Introduction

In large organisations, the grouping of different elements on the basis of global objectives may be a way whereby specific goals can be more easily attained, by acting on the elements of each group alone. A case of this grouping arises in industry when designing flexible manufacturing systems on the basis of group technology. This may therefore be regarded as an alternative to the technology inherent in conventional production.

These flexible manufacturing systems have the particular feature of sharing a production philosophy founded on previously given orders. Each order consists of a small batch of products, while a high number of different orders are made during the same period of time. This calls for the introduction of different products, the incorporation of new materials and the adoption of different technological processes, all of which occur within a short period. To achieve enhanced competitiveness, a group-technology based flexible manufacturing system is required. This should be designed to enable efficient processing of small or medium-sized groups of different products, thus assuring a simplification of the productive process, through a reduction in the flow of tools, materials and products handled, besides a saving in production costs as a result of this system.

The two following industries share such particularities: the micro-electrical and the metal-cutting industry. For instance, in the Hewlett-Pacard micro-electrical company the circuit boards produced require different components. These are inserted in the actual boards by using automatic machines whose storage capacity is limited to no more than a given number of components (Hilllier & Brandeau, 1998; Ng, 2000). Another situation concerns the metal cutting plants. Here a set of computer-controlled tooling machines are needed to perform specific metal-part manufacturing operations, using auxiliary components: tools, tool magazines, pallets, fixtures, grippers and equipment to handle parts (Stecke, 1986). Each tool magazine has a limited storage capacity, although, provided the tools are loaded into the magazine, the machine automatically changes one tool for another to perform a different operation.

If we analyse these examples, we find that in both customized productions there are many types of printed circuit boards or metal parts, but the number that must be produced of each type is small. Another important similarity peculiar to both industries is that common components are inserted in different printed circuit boards, and identical tools are employed to manufacture different types of parts. Although the number of common components/tools is not that high, it is significant to cause this feature to be borne in mind when planning the productive process. Moreover, precedence constraints in both industrial processes should not be overlooked. Careful structuring of these production systems is a must. This involves firstly contemplating family grouping of circuit boards that incorporate identical components, or metal parts that share identical tools and later the assignment of each family to a machine or cell of machines. This structuring process helps one to secure considerable gains in terms of time and energy and, subsequently, to significant final manufacturing profits.

In such contexts the problem of part families with precedence constraints (PFP), described in Section 2, arises. Section 3 is devoted to the improved genetic heuristic. Here the encoding of each solution through a chromosome is given, as is characterisation of the genetic operators that modify the chromosome population, besides the improved local search procedure to be applied to the most fitted chromosomes of the population. Section 4 refers to two mathematical programming models for the PFP, both with binary variables but one is quadratic and the other linear. Section 5 concerns the computational experiment undertaken to compare the results of the genetic heuristics (the basic and the improved versions) with those obtained by a special purpose constructive heuristic and by the CPLEX applied to