Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia CIRP 7 (2013) 37 – 42

www.elsevier.com/locate/procedia

Forty Sixth CIRP Conference on Manufacturing Systems 2013

Manufacturing Network Design for Mass Customisation using a Genetic Algorithm and an Intelligent Search Method

Mourtzis D.[a]*, Doukas M.[a], Psarommatis F.[a]

[a] Laboratory for Manufacturing Systems and Automation, University of Patras, 26500, Greece
* Corresponding author. Tel.: +30-2610-997262; fax: +30-2610-997744. *E-mail address*: mourtzis@lms.mech.upatras.gr.

Abstract

The volatile globalised markets and mass customisation greatly affect modern industries. In this context, the timely and accurate manufacturing network design is an important strategic decision. However, this proven NP-hard problem cannot be approached by exhaustive methods. This research work aims to support the decision-makers by introducing a Genetic Algorithm for the identification of near optimum manufacturing network configurations. The examined problem tackles the multi-stage manufacturing network design for single customised products, through satisfaction of multiple objectives. The performance of the alternative designs deriving from the GA is compared to the results of an intelligent search algorithm with adjustable control parameters, and with an exhaustive search method. The conflicting criteria for evaluating the alternative configurations include cost, time, quality and environmental parameters. The applicability of the proposed method is validated through a case study, utilising data acquired from the automotive sector.

Selection and peer-review under responsibility of Professor Pedro Filipe do Carmo Cunha

Keywords: Genetic Algorithm; Manufacturing Network Design; Decision-making

1. Introduction

The emerging product personalisation trend and the market volatility caused primarily due to the recent global economic recession heavily affect manufacturing industries [1]. The effects are further intensified by the ever-existing need to reduce costs, time and environmental impact, and improve quality. In this landscape, the manufacturing network design problem constitutes an utterly important task [2]. This research work aims to support supply chain decisions in the context of mass customisation, through the introduction of a multi-objective decision making genetic algorithm.

2. State of the Art

The volatility of the global markets has intensified during the last 5 years, owing to the global economic recession, natural and other disasters (e.g. Icelandic volcano eruption) [3]. Moreover, the mass customisation paradigm and the implications it generates on manufacturing systems has been studied extensively during the last decade [4, 5, 6]. Especially the issue of identifying efficient manufacturing network configurations has attracted significant attention [7].

Genetic Algorithms (GA) have been widely employed for tackling problems related to manufacturing network design, logistics and shop-floor scheduling problems. GAs are stochastic global search optimisation methods based on the evolutionary ideas of natural selection and genetics [8]. Recent GA applications to the manufacturing network design problem are discussed hereafter. A GA application over a supply chain order distribution problem was discussed in 2004, in combination with Analytic Hierarchic Process (AHP) [9]. The AHP comprised the decision-making mechanism and was used for evaluating the fitness of the chromosomes of each generation. A GA with a novel encoding mechanism and a new crossover operator was introduced by Gen et al. [10]. The method addressed a two-stage transportation problem, focusing on the capacity allocation over a scalable network of manufacturing plants, distribution centres and potential customers. The method was further enhanced for a multi-stage, multi-product supply chain network design [11] and improved for multiple objective optimisation [12]. A framework that included a GA where the selection of

2212-8271 © 2013 The Authors. Published by Elsevier B.V.
Selection and peer-review under responsibility of Professor Pedro Filipe do Carmo Cunha
doi:10.1016/j.procir.2013.05.007

individuals was performed through computer simulation was presented in 2006 [13]. A steady state GA was developed in [14], and was benchmarked against the solution provided by a hybrid GA and through a simulated annealing method. A novel encoding/decoding method for the chromosome representation was proposed by Costa et al. in [15] which effectively reduced the generation and selection of non-feasible solutions for the supply chain order distribution problem. Co-evolutionary approaches with application on realistic manufacturing network design problems [16] and dynamic job-shop scheduling [17, 18] have also been proposed.

The proposed research work focuses on the identification of efficient multi-stage and single-product manufacturing network configurations, through optimisation of multiple objectives. The methods used for that purpose are a GA, an Intelligent Search Algorithm (ISA) and an Exhaustive Search method (EXS). The approach is validated through a real life case study utilising data acquired from the automotive industry.

3. GA for Manufacturing Network Design

An optimisation problem involves finding values for variables that minimise or maximise an objective function, while satisfying the set of constraints. In such problems, some solutions will be the best among others. The space of all feasible solutions is called search space. Each point in the search space represents a possible solution. Each possible solution can be marked by its value, i.e. fitness in the population methods, including the GA approach [8].

GAs begins with a set of potential solutions called population, where each solution is represented by a chromosome. Solutions from one population are selected, modified according to the GA operators (selection, crossover, mutation) and used to form a new population, in order to form a new population better than the old one. Solutions are selected according to their fitness; the "fittest" a solution is, the more chances it will have to reproduce, carrying its genes to the next population. This is repeated until a termination condition is met (Fig 2). The *encoding* of the chromosome is carried out using integer values. Each gene holds an integer value, which represents the supply chain partner assigned to a specific manufacturing task. Therefore, a chromosome represents a manufacturing network alternative.

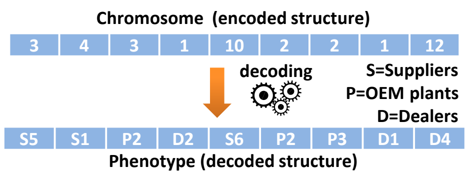

Fig. 1. Encoded and decoded structure of a potential solution

This encoding type apart from its suitability with regards to the nature of the investigated problem, greatly simplifies the decoding procedure. The chromosomes are decoded into phenotypes, which hold the actual information regarding the manufacturing network configuration, i.e. selected manufacturing network partner (Fig. 1). Decoding is performed each time there is the need to evaluate the fitness of chromosomes and make the "survival of the fittest" selection.

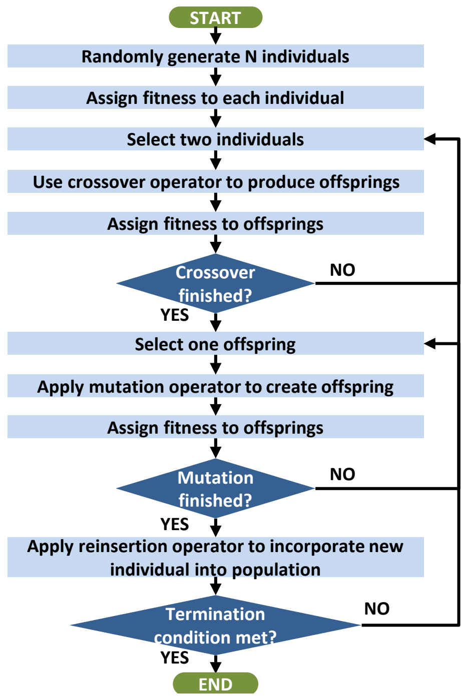

Fig 2. Flowchart of the GA (Adapted from [19])

The *selection operator* utilised is Stochastic Universal Sampling [20], which uses a single random value to sample all of the solutions by choosing them at evenly spaced intervals, i.e. F/L in the diagram of Fig. 3.

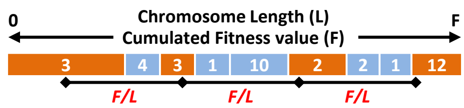

Fig. 3. Stochastic Universal Sampling selection example

The *crossover operator* mates two parent chromosomes to produce offspring chromosomes. Shuffle crossover is used, where the position of genes of the parent chromosomes' strings are randomly shuffled between crossover points, the segments are exchanged and the strings are un-shuffled. This entails the advantage that after recombination positional bias is removed as the variables are randomly reassigned at each iteration [21].