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Optimization of the material flow in a manufacturing plant by use of artificial bee colony algorithm

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ABSTRACT

To survive in today's competitive global market, companies must perform strategic changes in order to increase productivity, eliminating wasted materials, time, and effort. This study will examine how to optimize the time and effort required to supply raw material to different production lines in a manufacturing plant in Juarez, Mexico by minimizing the distance an operator must travel to distribute material from a warehouse to a set of different production lines with corresponding demand. The core focus of this study is similar to that of the Vehicle Routing Problem in that it is treated as a combinatorial optimization problem. The artificial bee colony algorithm is applied in order to find the optimal distribution of material with the aim of establishing a standard time for this duty by examining how this is applied in a local manufacturing plant. Results show that using this approach may be convenient to set standard times in the selected company.

1. Introduction

Lean manufacturing is a production strategy that is being applied to virtually every industry worldwide. A lean environment can minimize waste by eliminating, combining, or simplifying unnecessary movements (Meyers & Stewart, 2001). Waste can be found everywhere: staff waiting for an indication, material waiting to be processed, labor waiting for tools, defective raw material, processes without defined time standards, etc. The competitive nature of global competition forces manufacturing companies to always look for innovative approaches to improve and optimize their processes. It is imperative for companies to stay up to date with the latest methodologies and technological advances in order to remain competitive (Nemhauser, 1994).

Today's executives require constant vigilance from their employees in terms of cost savings and productivity. Businesses should continually strive to make process improvements, regardless of how small, or risk becoming obsolete.

One of the key factors in manufacturing facilities that are in constant improvement is the optimization of the process flow. It is considered that the flow is the most important parameter of a production system (Meyers & Stewart, 2001); almost all improvements are reflected directly into the flow through a plant which directly impacts the costs of the organization. Thus, it is necessary to have mechanisms to coordinate the development of production activities with distribution in order to achieve efficient production systems. Planning of material flow through a company organizes and optimizes the flow of raw materials into production systems in order to optimize operations. Minimizing flow costs means minimizing overall production costs.

Material flow may be defined as the structured and organized movement of material from point *X* to point *Y* in the entire production system taking into account the efficient use of space and cost savings such as energy and human resources (Meyers & Stewart, 2001). Material flow is a complex process in the production system and cannot be optimized without planning. The optimization of material flow can be carried out in the planning of a new plant or in an existing production site. It is likely to occur in different areas depending on the organization. For instance, optimizing the flow of material coming from the warehouse to various existing production lines, among other areas of the company where might be optimized the flow of material or information. Therefore, if it is consider the optimization of material flow from a warehouse to certain production lines, it can be done an analogy of this problem with the Vehicle Routing Problem (VRP).

For this problem, many researchers have explored various methods that can be classified as either exact algorithms or metaheuristics but for this type of problems (combinatorial optimization) the use of metaheuristics is considered a reasonable approach to find ideal solutions in a considerable time. Research in combinatorial optimization problems based on metaheuristics algorithms has gained popularity since the 1990s. These algorithms seek approximate solutions in polynomial time instead of exact solutions which require an extreme computational power and time which sometimes is inefficient in real life problems. In

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order to find the solution of the VRP, a large variety of algorithms have been applied such as Tabu search (Gendreau, Hertz, & Laporte, 1994; Osman, 1993; Tang-Montane & Dieguez-Galvao, 2006), Simulated Annealing (Chiang & Russell, 1996; Van Breedam, 1995; Woch & Lebkowski, 2009), Genetic Algorithms (Baker & Ayechew, 2003; Berger & Barkaoui, 2003; Daza, Montoya, & Narducci, 2009; Ombuki, Ross, & Hanshar 2006; Prins, 2004; Torres, Serrato, & Rayas, 2011), and Swarm intelligence algorithms (Bell & McMullen, 2004; Marinakis, Marinaki, & Dounias, 2011; Ai & Kachitvichyanukul, 2009; Ding, Hu, Sun, & Wang, 2012; Kanthavel & Prasad, 2011; Shen, Zhu, Liu, & Jin, 2009; Tan, Lee, Majid, & Seow, 2012; Venkatesan, Logendran, & Chandramohan 2011; Yu, Yang, & Yao 2009).

While the above metaheuristics have been used widely and successfully applied to the VRP, Artificial Bee colony (ABC) algorithm (part of the swarm intelligence algorithms) is a fairly new approach which was introduced few years ago by Dervis Karaboga (2005). When it was applied to similar problems it has been found to produce excellent results as well as reducing computational time (Bhagade & Puranik, 2012; Brajevic, 2011; Ji & Wu, 2011; Shi, Meng, & Shen, 2012; Szeto, Wu, & Ho, 2011). The main objective of this study is twofold: first, to plan the material flow in order to establish a standard time by implementing the Artificial Bee Colony algorithm since the material leaves the warehouse and it is distributed to each production line. This is carried out within a manufacturing plant located in Ciudad Juarez, Chihuahua, Mexico. Second, as it was stated above, not only new technologies have emerged recently but also new algorithms have arisen. Thus, there is a question every manufacturing plant in Mexico should ask themselves: is it necessary to start to invest in new methodologies, and not only in advanced manufacturing technologies, in order to improve productivity? The answer to this question is straightforward: Yes. Many companies around the world are developing and implementing techniques such as heuristics, however this type of approaches seem far away in this region of the country (Juarez, Mexico), which is one of the primary manufacturing zones in the country. It is important to mention that this sector (Juarez), represents 50% of the exports of the manufacturing automotive sector in Mexico and the assembly plants association AMAC (Asociación de maquiladoras A.C.) has in its records 352 enterprises as members in different areas, this data indicates the economic importance of this region (INEGI, 2010). Therefore, this work might help to demonstrate that it is time to evolve to different approaches than the typical ones implemented so far, specifically in the industry located in Juarez, Chihuahua, Mexico.

This paper is distributed as follows: Section 2 presents a brief background about VRP and ABC based on codification of permutations. Section 3 presents an experimental case applied to a manufacturing plant in Ciudad Juarez Mexico. The final section provides the corresponding conclusions.

2. Background

2.1. Vehicle routing problem

The Vehicle routing problem (VRP) is a classical combinatorial optimization problem and belongs to the type NP-hard, for which there is no polynomial time algorithm that can provide an optimal solution. In the classical VRP, the objective is to minimize the total traveled distance from a central depot to a set of different points (customers, stores, warehouses, production lines, etc.), where the distance between points and depot is known in advance C_{ij}. Each point is serviced exactly once by a single vehicle which has a limited capacity q and the demands of each point d_i are known in advance. Capacity constraint is violated if the total sum of the point demands in a given route exceeds the vehicle capacity. Hence, vehicles must go back to the depot to load and continue the route. Fig. 1 shows a simple graphical representation of the VRP and a possible solution. In this example, there are 11 points that have to be visited once; there are 3 routes, route 1 with 5 points, route 2 with 4 points, and route 3 with 2 points.

2.2. Artificial bee colony algorithm

Artificial bee colony (ABC) algorithm is an optimization algorithm based on the intelligent behavior of honey bees developed by Dervis Karaboga in 2005 Karaboga (2005). In the ABC algorithm, the colony of artificial bees is composed of three groups of bees: employed, onlooker, and scout bees. The first half of the colony consists of employed bees and the second half is composed of onlookers. An onlooker bee is the one waiting in the dance area for making a decision of choosing a food source. Each food source is represented by an employed bee. Once a food source is exhausted, the employed and onlooker bees become scout bees.

Basically, the ABC algorithm consists of three steps:

(1) Sending the employed bees into the food sources and evaluating their nectar amounts
(2) Selecting the food sources by the onlooker bees after sharing the information of the employed bees
(3) Selecting the scout bees and sending them into possible food sources

Mathematically, in the ABC algorithm a food source corresponds to a possible solution of an optimization problem and the nectar amount represents the objective function of the solution. The number of employed bees or onlooker bees represents the number of solutions in the population (SP). A random initial solution is generated in the ABC algorithm with SP solutions (food sources positions). Each solution is a D-dimensional vector x_i ($i = 1,2,\ldots,D$), where D is the number of optimization variables in the problem. The population of solutions is subject to iterative cycles, $C = 1,2,\ldots,C_{\max}$, of the search processes of the employed, onlooker, and scout bees. A new solution (new food source) is generated when an employed or onlooker bee produces probabilistically a variation in the current food position (current solution) for finding a new food source (new solution). If the nectar amount (objective function value) of the new food source is higher than the old one, then the bee memorizes the new food position and forgets the previous one. Once the search process performed by the employed bees is completed, they share the nectar amount and position of the food sources with the onlooker bees within the dance area. The onlooker bees then evaluate the information and selects a food

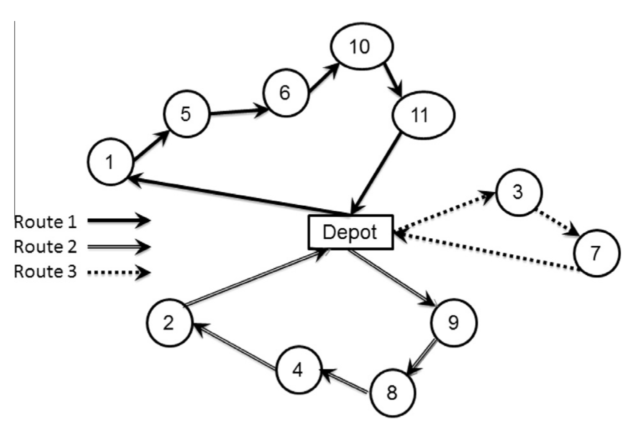

Fig. 1. Routing solution for VRP.