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Hybrid Metaheuristic to Optimize Traceability in the Food Industry

Saima Dhouib, University of Sfax, Tunisia

ABSTRACT

In this paper, the authors propose a new hybrid metaheuristic to solve the problem of manufacturing batch dispersion. The method consists of inserting the record to record travel algorithm (RRT) in the artificial bee colony (ABC) in order to ensure balance between the diversification and the intensification phases. The new technique is named RRT-ABC, and it starts by launching the standard ABC, and then the onlooker research phase is enriched by the RRT algorithm. So, the main idea of this research work is to solve the NP-hard problem of minimizing the batch dispersion using a novel metaheuristic because of the limitation of exact methods. Experimental results, carried on sausage manufacturing in a French food industry, proved the highly efficient performance of the proposed RRT-ABC metaheuristic.

KEYWORDS

Artificial Bee Colony Algorithm, Batch Dispersion, Food Industry, Metaheuristic, Record to Record Travel Algorithm, Traceability

1. INTRODUCTION

Due to the highly competitive and continuously changing markets, companies have to evolve introducing traceability systems as a response to the internal and external forces of the environment (Bougdira et al., 2020; Millard et al., 2015; Barge et al., 2014; Sahin et al., 2002). The traceability systems have a potential impact on all the enterprise systems (manufacturing, information, decision, etc.). So, when designing and making evolve these systems, it is required to integrate them properly in a given context, in order to enabling them to contribute to the enterprise performance (Haleem et al., 2019; Olibeirav et al., 2019 ; Dai et al., 2015; Miller et al., 2014; Xu, 2010; Papper et al., 2002).

The traceability system establishes precisely the history of composition and location of products all along the supply chain (Sameer, 2011; Regattieri et al., 2007). But such a system does not decrease the amount of products recalled in case of production batch mixing. The problem under study tries to control the mixing of production batches in order to limit the size, and consequently the cost and the media impact of batches recalled in the case of the problem. (Dupuy et al., 2005) proposes a mathematical model for sausage manufacturing in a French food company. This sausage company provides 3-level disassembling and assembling bill of material. It aims to reduce batch dispersion in order to optimize traceability. It is a NP-hard problem (Tamayo et al., 2009).

Our aim in this paper is to develop an efficient hybrid metaheuristic having a simple structure and generating high-quality solutions: The Record to Record Travel-Artificial Bee Colony (RRT-ABC) metaheuristic. This RRT-ABC starts by applying the standard Artificial Bee Colony (ABC) metaheuristic and then the onlooker research phase is ameliorated by applying a local research method

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(the Record to Record Travel (RRT) method). The proposed hybrid method RRT-ABC ensures good balance between the diversification and the intensification phases.

To improve the performance of the Artificial Bee Colony metaheuristic (ABC) for solving the problem of batch dispersion, we have applied the hybridization of this method with an approximate local search method which is the Record to Record Travel (RRT).

Through this article, we propose a hybrid RRT-ABC method to minimize the quantity of recalled products in the case of a particular nomenclature with three levels of raw materials disassembled in assembled components and into final products. Our new hybrid method has been applied for the problem of batch dispersion, encountered in the sausage process as proposed by (Dupuy, 2004).

To illustrate our work and prove the performance of this method, tests and comparative analyses of this new method are carried out.

The remainder of the paper is organized as follows. In section 2, we present the state of the art of the manufacturing batch dispersion problem as well as the RRT and the ABC metaheuristics. Then in section 3, we describe our research methodology. Computational results, discussion and convergence behaviour of the proposed RRT-ABC are reported and analysed in section 4. Section 5 concludes the paper and suggests future research directions for our new method application of our new method RRT-ABC.

2. STATE OF THE ART

The main interest of traceability is to manage food crisis: Food companies aim to reduce the cost of recalls, in term of products quantity (Aung et al., 2014; Dabbene et al., 2014). A way to reduce this cost is to reduce batch size and batch mixing in order to reduce the recalled batch size (Storoy et al., 2013). (Dupuy et al., 2005) suggests a mathematical model for Food companies to minimize the total dispersion (See Figure 1.). The goal is to find the quantities corresponding to the sub-product batches to obtain the lowest possible raw materials dispersion according to the cutting and assembling nomenclatures. This problem presents 4 batches of raw materials divided into 2 types, 6 batches of components divided into 2 types, 2 batches of bought components (one of each type) and 4 batches of finished products divided into 2 types. This problem is formulated as follow using a mixed mathematical programming model and it is solved by LINGO 6.0 software to optimize traceability by minimizing the total dispersion.

The descending dispersion of a raw material batch is the number of batches of finished products which contain a part of this raw material. The ascending dispersion of a finished product batch is the number of raw material batches used in this finished product. The total dispersion of a system is equal to the summation of the descending dispersions of all finished products.

(Dupuy, 2004) showed that the resolution of the problem previously described by using the exact methods is limited because as soon as the number of data increases, the resolution time gradually increases such as in the case of using 4 batches of raw materials, 6 batches of components, 4 batches of finished products and 2 batches of purchased components. This case generates 142 variables (56 integers) and 244 constraints with an overall optimum of 6 hours of resolution time with 1.2 GHz Pentium PC III. In addition, when the number of used batches is increased, the number of variables and constraints will automatically be enormously important, such as the case of the use of 8 batches of raw materials, 12 lots of finished products and 8 batches of components. This case generates 1292 variables (576 integers) and 3684 constraints and the calculation time was stopped after 12 hours of calculation, without the global optimum having been found (approximately 50,000,000 iterations).

According to (Tamayo et al., 2009), the problem of batch dispersion is a NP-hard problem and it is similar to the problem of fixed-cost transport proposed by (Palekar et al., 1990). Sources represent batches of raw materials, intermediate nodes are the bundles of components and the destinations are the bundles of finished products. The arcs model the disassembly or assembly links of the nomenclature. A quantity is assigned for each use of an arc. The sum of links between raw material batches and finished

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