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Gravitational Search Algorithm for Assembly Sequence Planning

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Abstract - Assembly sequence planning (ASP) refers to the process of arrangement of a particular assembly sequence with regard to a product design. In assembly sequence planning, the relationships between components such as the geometry of compliant assemblies should be taken into account before a precedence diagram is eventually built and feasible assembly sequences can be generated. A better assembly sequence can contribute to reduce the cost and time of the manufacturing process, that is, among NP-hard problems. Thus, it is needed to find the optimal sequence from the feasible assembly sequences. In past few years, many optimization techniques have been used to solve the assembly sequence planning problem include Simulated Annealing (SA), Genetic Algorithm (GA), and binary Particle Swarm Optimization (BPSO). In this paper, an approach using Gravitational Search Algorithm (GSA) which is a heuristic optimization algorithm that incorporates the Newton's law of gravity and the law of motion into analytical studies of systems is proposed to solve the assembly sequence planning problem. The experimental results show that the proposed approach is more efficient in solving the assembly sequence planning problem, with less of total assembly time in comparison with the three other approaches.

Keywords – Assembly sequence planning. Meta-heuristics. Gravitational search algorithm. Precedence matrix.

1. Introduction

Assembly sequence planning, which is an important part of assembly process planning, plays an essential role in the manufacturing industry. The focus of ASP is to determine the order of assembly of a product in the assembly line to shorten the assembly time or save the assembly cost [1].

Assembly sequence planning consists of assembly, operations, existing assembly techniques and some details of relations between parts [2]. Some researchers have dedicated their work on some important issues related to concurrent engineering analyses on assembly sequence planning [3]. These issues are the representation of a product to be assembled, the generation of assembly sequence plans and the determination of precedence constraints, the representation of resulting assembly sequence plans and the selection of the optimum assembly sequence planning.

Many works have intensely done on assembly sequence planning systems using meta-heuristics approaches [4-6]. The implementation of meta-heuristics in solving discrete optimization problems, particularly in the ASP problem lead to significant reduction of computational times, which by its nature sacrifices the guarantee of finding exact optimal solutions [7,8]. However, these approaches are permitted to obtain acceptable performance at acceptable costs in a large number of possible assembly sequences. In other words, these approaches able to find good solution on large-size problem instances.

In past few years, a stochastic population-based meta-heuristic called Gravitational Search Algorithm (GSA) has been developed [9]. GSA is inspired by the Newton's law of universal gravitation where all objects attract to each other with a force of gravitational attraction.

In this paper an assembly sequence planning problem is solved using a GSA-based approach. The objective is to generate the optimal assembly sequence to minimize production time. At the same time, production cost can be save.

2. Gravitational Search Algorithm

The computational of GSA requires a set of N agents, which are randomly positioned in the search space during the initialization. The position of agents, which are the candidate solutions to the problem are represented as:

$$X_i = \left(x_i(1),\ldots,x_i(d)\ldots,x_i(n)\right) \text{for } i = 1, 2, 3,\ldots N \tag{1}$$

where $x_i(d)$ presents the position of i^{th} agent in the d^{th} dimension, and n is the space dimension.