

An AIS-based Hybrid Algorithm with PSO for Job Shop Scheduling Problem

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Abstract: Job Shop Scheduling Problem (JSSP) is a traditional NP-hard combinational optimization problem. In this paper, we propose a new hybrid method based on Artificial Immune Systems (AIS) and Particle Swarm Optimization (PSO) to solve JSSP with an objective of minimizing the makespan while satisfying the predefined constraints. Two AIS theories, namely, clonal selection theory and immune network theory are adopted. The former establishes the fundamental processes including selection, cloning, hypermutation and receptor editing, and the latter increases the diversity for the potential solution set. For the random hypermutation process, PSO is applied to optimize and accelerate the search process. This algorithm is tested on 20 benchmark problems with four different sizes. The results shows that its performance is encouraging, especially for small size problems.

Keywords: Job Shop Scheduling Problem (JSSP), Artificial Immune Systems (AIS), Particle Swarm Optimization (PSO), Clonal Selection, Immune Network.

1. INTRODUCTION

Job Shop Scheduling Problem (JSSP) being a classical combinational optimization problem, is known to be NP-hard (Garay and Johnson, 1979) where the global optimal solution is difficult to be found in polynomial time. As the problem prevails in production and manufacturing industries and is inherently difficult, it has attracted many researchers who engaged in developing effective optimization algorithms for this problem. Hence, a wide variety of approaches and algorithms for solving the problem generated.

Generally speaking, these solution methods can be divided into two types, namely, optimization methods and approximate methods. The former evaluates an exact solution and these methods include integer programming, dynamic programming, Lagrangian relaxation, enumeration, branch and bound (B&B) methods. Among these, the B&B algorithm is the most useful and is adopted by many researchers. As a result, plenty of research has been focused on this method and considerable improvement work has been made. However, as the problem size grows, this kind of method becomes inefficient and time-consuming because the problem grows to be computational complex. It cannot be used in solving large problems within a reasonable time. As such, the research direction has turned to the approximate approaches.

Although approximate methods do not guarantee obtaining the global optimal solutions, they are able to find near-optimal solutions for larger problems, even for difficult problems in moderate computing time. Glover and Greenberg (1989) has suggested that a direct tree searching process is

totally unsatisfactory for difficult combinatorial problems and the heuristics inspired by natural phenomena and artificial intelligence are more suitable. Therefore, this type of method has attracted more attention. Currently there are four groups of frequently-used heuristics-based techniques: priority dispatch rules, bottleneck based heuristics, artificial intelligence and local search methods.

Approximation methods for solving JSSP were first developed based on the priority dispatching rules (PDRs). Although PDRs is a very popular technique because of its ease of implementation and significantly reduced computational requirement (Gelders, 1982), it only considers the current state of the schedule process, which makes the solution quality become poor and deteriorate as the problem size grows. Later the shifting bottleneck procedure (SBP) was proposed by Adams et al. (1988) which requires a certain level of programming technique. With the advance of computer technology, the researchers start to focus on the artificial intelligence and local search methods in the last decade. Artificial Intelligence (AI) develops on the biological understanding and uses principles in nature to find solutions. The most famous one used in JSSP is the neural network method (Jain and Meeran, 1999). It is inspired by the brain structure of simple living organisms that information processing is carried out through a huge interconnected network of parallel processing units. A review of the application of this method in scheduling problem is presented by Wang and Brunn (1994). Another type, the local search method, is based on the neighborhood structure and the rules defining how to obtain a new solution from the current one. Its general idea is to modify current solutions in a certain sense where the modification method is defined by a

neighborhood operator to generate a new feasible solution, which makes improvement on the objective value. Different neighborhood operators or rules generate different meta-heuristic methods. The most famous ones adopted for JSSP include simulated annealing (SA) (Vanlaarhoven et al., 1992), taboo search (TS) (Taillard, 1994), genetic algorithm (GA) (Wang, 2003), ant colony optimization (ACO) (Ventresca and Ombuki, 2004), and particle swarm optimization (PSO) (Xia and Wu, 2006). All these methods are well studied and some modified ones perform well. Currently, research effort has focused onto the development of hybrid methods which make full use of the advantages of each method. For JSSP, hybrid methods are frequently used with potential, such as hybrid GA-TS (Moon and Lee, 2000), hybrid genetic and ant colony heuristics (Girish and Jawahar, 2009), hybrid TS-ACO (Eswaramurthy and Tamilarasi, 2009), hybrid PSO based on SA (Xia and Wu, 2006). Experimental results show that most of the hybrid methods perform better than the individual method because they can help each other escape from the local search space and accelerate the convergence rate by taking strengths and avoiding weaknesses. A comprehensive survey of job shop scheduling techniques was undertaken by Jain and Meeran (1999).

According to the ‘No Free Lunch’ theorem (Wolpert and Macready, 1995), no algorithm is always more advanced than others when compared over all possible issues and every method can exceed at least one subset of certain functions. Therefore, for the JSSP, no one method can be definitely efficient in all situations. Furthermore, as the problem size grows, it becomes more difficult to solve the problem for any method. Therefore, there is much room for research to make improvement to existing methods. In recent years, a relatively new theory, called artificial immune systems (AIS) (Timmis, 2002), which is inspired by the human immune system, has been receiving extensive attention due to its successful adaptation to many combinatorial optimization problems. Simulating the human immune system, AIS provides many appealing features which makes it unique from other evolutionary algorithms, including self-learning, long lasting memory, cross reactive response, discrimination of self from non-self, and strong adaptability to the environment (Timmis, 2002). As such, AIS has been applied in a wide variety of fields, including pattern recognition, clustering, computer security, anomaly detection, optimization, machine learning, scheduling, and control (Hart and Timmis, 2005; Dasgupta et al., 2003). For scheduling, AIS has been successfully applied to the flow shop scheduling problem (Engin and Doyen, 2004), JSSP (Chandrasekaran et al., 2006; Coello et al., 2003), resource constraint project scheduling problem (Agarwal et al., 2007), multiprocessor scheduling (Wojtyla et al., 2006), etc. Yet, there are few hybrid AIS methods for solving JSSP. Furthermore, a large number of AIS mechanisms and theories have not been adopted for JSSP. As a result, in this paper, we proposed a new hybrid AIS-based algorithm where the meta-heuristics PSO is integrated. Although combining AIS with PSO for JSSP has been described by Ge et al. (2008), our idea has great differences in the hybrid mode and the modifying method for PSO when applied in JSSP. Our algorithm presents good performance in terms of solution accuracy and computational efficiency.

The remainder of this paper is organized as follows: In Section 2, JSSP is briefly introduced. Section 3 describes the proposed hybrid algorithm and outlines the steps for solving JSSP. Section 4 presents the experimental study and the results for the benchmark problems that measure the performance of the proposed algorithm. Finally, conclusions are presented in Section 5.

2. PROBLEM FORMULATION

The JSSP is a classical problem that can be described as follows: There are n jobs to be processed on m machines, with which the processing of each job consists of m operations to be performed. The task is to schedule all the operations of jobs on each machine to meet the predefined ultimate goal, such as minimizing the makespan, flowtime or tardiness, without violating the following assumptions: (1) All jobs and all machines are released at the beginning of the process. (2) The processing time of each operation is known in advance. (3) Each job should be processed by each machine exactly once in a predefined order. (4) A job cannot be operated by more than one machine simultaneously. (5) Each machine can manage only one operation at a time. (6) The operation processing cannot be interrupted, and there are no any unexpected events or disturbances. (7) The jobs can wait between two machines and the intermediate storage is unlimited. (8) Other factors, such as the setup time of the machine, transportation time, and resource cost, are neglected.

In this paper, we consider JSSP with the objective of minimizing the makespan while satisfying the above hard constraints.

3. THE PROPOSED HYBRID ALGORITHM

The proposed hybrid algorithm is developed based on the mechanisms of AIS and PSO. We firstly outline the basic principles of each theory, and then integrate these two theories and introduce the hybrid algorithm for JSSP.

3.1 Artificial Immune Systems (AIS)

Artificial Immune Systems (AIS), a class of biologically inspired computation paradigm, is developed based on the abstraction of the human immune system metaphors, with mathematical and computational modeling to provide algorithms and system design methodologies in the domain of engineering (Timmis, 2002).

The immune system is an effective and efficient defense mechanism that protects our body from the invading foreign substances, called antigens. It can recognize various antigens, even those previously unseen pathogens (learning), and remember them for future encounters (memory). It mainly works through two types of lymphocytes, B-cell and T-cell. The former is responsible for the humoral immunity that secretes antibodies binding to antigens by clonal proliferation. The latter is used to help destroy pathogens directly. These immune cells work in a corporative environment to fight

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