# Chapter 7
# Nature-Inspired Algorithms for Bi-Criteria Parallel Machine Scheduling

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## ABSTRACT

*Nature has always been a source of inspiration for human beings. Nature-inspired search-based algorithms have an enormous computational intelligence and capabilities and are observing diverse applications in engineering and manufacturing problems. In this chapter, six nature-inspired algorithms, namely artificial bee colony, bat, black hole, cuckoo search, flower pollination, and grey wolf optimizer algorithms, have been investigated for scheduling of multiple jobs on multiple potential parallel machines. Weighted flow time and tardiness have been used as optimization criteria. These algorithms are very efficient in identifying optimal solutions, but as the size of the problem increases, these algorithms tend to get stuck at local optima. In order to extract these algorithms from local optima, genetic algorithm has been used. Flower pollination algorithm, when appended with GA, is observed to perform better than other counterpart nature-inspired algorithms as well as existing heuristics and meta-heuristics based on MOGA and NSGA-II algorithms.*

## INTRODUCTION

The problem of scheduling *n* jobs on *m* parallel potential machines for optimizing bi-criteria, namely, maximum tardiness (minimize) and weighted flow time (minimize) is one of the important problems that is often encountered by engineers. The number of possible job sequences obtained by allocation of these *n* jobs on m machines is exponentially large and identifying best sequence out of them especially when *m* or *n* is large is NP-hard (Mazdeh, Zaerpour, Zareei, & Hajinezhad, 2010). Nature-inspired algorithms such as Artificial Bee Colony (ABC) (Akbari, Hedayatzadeh, Ziarati, & Hassanizadeh, 2012), Bat (Yang, 2011), Black hole (BH) (Hatamlou, 2013), Cuckoo Search (CS) (Yang & Deb, 2009), Flower Pollination (FPA) (Yang, Karamanoglu, & He, 2013), Grey Wolf Optimizer (GWO) (Mirjalili, Saremi, Mirjalili, & Coelho, 2016) algorithms have the ability to handle such optimization problems.

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One of the possible applications of the problem under consideration is scheduling of large number ($n$) of processes on multiple processors (m*)* by the operating system. In such a system, numbers of processors (CPU) (as machines) are available all the time in parallel and number of processes (jobs) are to be scheduled on these processors. Each of the process (job) has its own processing time and priority. The processes are to be scheduled on available parallel processors such that there is maximum tardiness as well as weighted flow time for the processes are minimum. This could lead to increase in the throughput rate for the running processes. Further, use of parallel processors enhances production as the work does not stop when some processors fail or maintenance occurs.

The multi-objective formulations of ABC, BAT, BH, CS, FPA, and GWO algorithms obtained by the combination of weighted objectives or auxiliary archive for managing possible solutions along with their hybrids with GA have been developed and applied to the problem of scheduling jobs on machines running in parallel in order to optimize bi-criteria, namely, maximum tardiness and weighted flow time. The algorithms are applied on randomly generated sample for scheduling 40 and 60 jobs on 2, 3 and 6 machines. The proposed approaches are compared to existing meta-heuristics based on MOGA (Deb, 2014) and NSGA-II (Deb, Pratap, Agarwal, & Meyarivan, 2002) algorithms as well as existing heuristic (Nailwal, Gupta, & Sharma, 2015).

## BACKGROUND

Scheduling of jobs on parallel machines is one of the prominent problems generally encountered in manufacturing and production engineering and has gained increasing attention in the past few decades. Numerous engineers and researchers are working on optimisation of different criteria for scheduling multiple jobs on multiple machines. In addition, novel meta-heuristic techniques have been actively used for scheduling of jobs on multiple potential machines. Some of the recent works eminent in the field are discussed in Table 1. Optimization criteria and heuristic being followed have also been listed in Table 1.

## RESEARCH OBJECTIVES

The main objectives of the proposed work are listed below:

- To experimentally evaluate the behaviour of recent-inspired algorithms such as ABC, Bat, BH, CS, FPA and GWO algorithms on scheduling of $n$ jobs on $m$ potential parallel machines.
- To evaluate the impact of adding crossover and mutation operator to these nature-inspired algorithms.
- To investigate use of auxiliary archive to maintain Pareto Front and hypercubes to maintain best solutions.
- Comparison of job schedules obtained by applying these hybrid nature-inspired algorithms to that of existing search-based approaches by taking summation of maximum tardiness and weighted flow time as comparison criteria.