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# Neural network and genetic algorithm-based hybrid approach to expanded job-shop scheduling

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## Abstract

The expanded job-shop scheduling problem (EJSSP) is a practical production scheduling problem with processing constraints that are more restrictive and a scheduling objective that is more general than those of the standard job-shop scheduling problem (JSSP). A hybrid approach involving neural networks and genetic algorithm (GA) is presented to solve the problem in this paper. The GA is used for optimization of sequence and a neural network (NN) is used for optimization of operation start times with a fixed sequence.

After detailed analysis of an expanded job shop, new types of neurons are defined to construct a constraint neural network (CNN). The neurons can represent processing restrictions and resolve constraint conflicts. CNN with a gradient search algorithm, gradient CNN in short, is applied to the optimization of operation start times with a fixed processing sequence. It is shown that CNN is a general framework representing scheduling problems and gradient CNN can work in parallel for optimization of operation start times of the expanded job shop.

Combining gradient CNN with a GA for sequence optimization, a hybrid approach is put forward. The approach has been tested by a large number of simulation cases and practical applications. It has been shown that the hybrid approach is powerful for complex EJSSP. © 2001 Elsevier Science Ltd. All rights reserved.

*Keywords*: Job-shop scheduling; Neural network; Genetic algorithm; Gradient search

## 1. Introduction

Scheduling is an old discipline that originated and developed almost in step with operations research starting in the 1950s. Johnson's algorithm for $n/2/F/C_{\max}$ and parts of the special $n/3/F/C_{\max}$ problems launched the research of scheduling theory in the 1950s. A series of representative scheduling problems were studied with pure integral programming, dynamic programming and branch and bound approach in the 1960s. Some heuristic algorithms were proposed for computing these complex problems in the last period of the 1960s. The intrinsic complexity of some scheduling problems was understood and many of them were proved to be intractable in the 1970s. The effective heuristics and their effectiveness have

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been intensively conducted since then. It can be said that classical scheduling theory reached maturity as a branch of applied mathematics since the end of the 1970s (Bark, 1974).

On the other hand, scheduling is also a young discipline. With the development of production technology and management, many new types of practical scheduling problem are emerging constantly and need to be solved. Working emphases have been shifted to solving practical problems. New techniques emerging from the field of AI have been introduced to this discipline since the 1980s.

The job-shop scheduling problem (JSSP) is a simplified version of real production scheduling problems. In this paper, a more realistic problem, namely the expanded job-shop scheduling problem (EJSSP), is studied. EJSSP considers various constraints such as job delivery due dates and resource available times in addition to those considered by the standard JSSP.

In general, the research approach to production scheduling falls into the following three categories: heuristic priority rules, combinatorial optimization (Dubois, Fargier & Prade, 1995), and knowledge-based system with intelligence (Shaw, Park & Raman, 1992).

Each method has its own drawbacks. Although priority rules, especially some heuristic priority rules have been applied extensively because of their simplicity and ease of implementation, the resulting scheduling results cannot be predicted beforehand. There are no systematic methods of designing heuristics for a specific scheduling task. Analytic optimization is a desired method because it is efficient. Unfortunately, there is no generally analytic optimization algorithm for intrinsically complex NP-hard combinatorial optimization problems. In the intelligent scheduling information system (ISIS), a knowledge-based scheduling system first developed by Fox (1994), the constraint propagation technique is applied to solve a practical scheduling problem. There is a long way to go before a comprehensive theory and system for scheduling is fully developed, even though ISIS arouses the enthusiasm of those studying practical production scheduling problems.

Recently, much attention has been paid to applying neural networks (NNs) and genetic algorithms (GAs) to production scheduling problems. There are three existing ways of scheduling tasks using NNs. One way is to take advantage of the parallel computing ability of NNs to solve scheduling optimization problems (Jain & Meeran, 1998). This method's drawback lies in its non-availability for universal scheduling problems, because there are no systematic means of constructing a proper energy function for them. The second way should be classified within the intelligent scheduling category, in which an NN is used to acquire scheduling knowledge by dint of its learning ability (Wang, 1995). The intelligent scheduling with NNs has given elementary results, but it needs a lot of supporting sample data and is not yet applicable to practical problems. The last way is to describe production constraints and encode scheduling rules in the NN. Intrinsically, this is one kind of heuristic scheduling. Only feasible schedules can result from the network's operation (Foo & Takefuji, 1988; Chang & Jeng, 1995; Willems & Rooda, 1994). The major problems in this approach are (1) lack of ability to acquire optimal solutions; and (2) suitability only for specific simple scheduling problems.

In recent years, an interest in applying intelligent computing methods to job-shop scheduling has grown rapidly. Steinhofel, Albrecht and Wong (1999) present two simulated annealing-based algorithms for the classical JSSP where the objective is to minimize the makespan. To overcome the problem that convergence of simulated annealing does not hold in the application to job-shop scheduling, Kolonko (1999) proposed a new approach that uses a small population of SA runs in the GA framework. Moreover, an SA algorithm using three perturbation schemes, viz. pairwise exchange, insertion, and random insertion, for job-shop scheduling is put forward by Ponnambalam, Jawahar and Aravindan (1999). Meanwhile, GA is also an efficient method for JSSP. Cheng, Gen and Tsujimura (1999a,b) summarize