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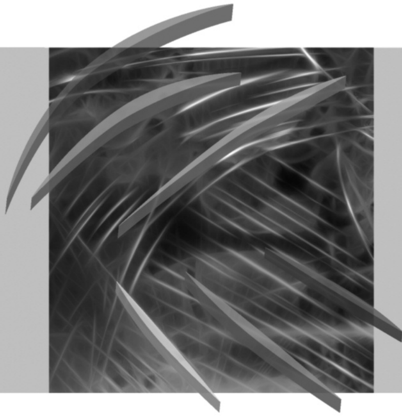

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Intelligent Technologies and Applications

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PLANNING AND SCHEDULING IN INDUSTRIAL CLUSTER WITH COMBINATION OF EXPERT SYSTEM AND GENETIC ALGORITHM

Abstract: In this paper, the author proposes an innovative method for planning and scheduling in industrial cluster called APRMC (Advanced Production Management in Cluster). The approach is implemented as a combination of expert system and genetic algorithm. The production planning problem is first solved, and then the scheduling problem is considered with the constraint of the solution. This research adopts the genetic algorithm developed by A. Ławrynowicz.

Keywords: industrial cluster, expert system, genetic algorithm.

1. Introduction

Various types of manufacturing networks can be formed by different classes of firms to respond to new market challenge. Clusters (and similar forms of interorganizational structures) create the environment for innovation and technological advancement. Cluster is a local supply network based on partnership [Ławrynowicz 2009b, 2010b]. An "industrial cluster" is defined as a geographical and sectoral concentration and combination of firms [Niu 2009]. Differently than in global supply networks where each node (i.e. enterprise) applies autonomous method for operations management, in the industrial cluster the management can be executed together. Considering the above aspects, the author suggests a new expert system and a genetic algorithm to solve planning and scheduling problems in supply networks.

Today, the efficient management of the new form of business needs new tools. To solve production planning and scheduling problems, many research studies have been widely conducted on heuristic algorithms, such as tabu search, simulated annealing algorithm, and genetic algorithm. But, first and foremost, the artificial intelligence techniques such as expert systems and genetic algorithm find a near-optimal solution in a reasonable computation time when the problem size is very large [Dayou, Pu, Ji 2009].

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Expert system (ES) is a program which has wide base of knowledge in a restricted domain and uses complex inferential reasoning to perform tasks which human expert could do [Welbank 1983]. ES also called knowledge based system (KBS) [Chtourou, Masmoudi, Maalej 2005] consists of three main components which include knowledge base, the inference engine and the user interface [Metaxiotis, Askoums, Psarras 2002]. The knowledge base is the heart of the system and contains the knowledge needed for solving specific problem. The knowledge may be in the form of facts, heuristic (e.g. experiences, opinion, judgments, predictions, algorithms) and relationships usually gleaned from the mind of experts in the relevant domain. Knowledge can be represented using a variety of representation techniques (e.g. semantic nets, frames, predicate logic), but the most commonly used technique is "If-Then" rules, also known as "production rules". The inference engine is employed during a consultation session, examines the status of the knowledge base, handles the content of the knowledge base and determines the order in which interfaces are made. It may use various interface methods. The user interface part enables interaction of the system with the user. In addition, expert systems provide interfaces for communications with external programs including data bases and spreadsheets. A detailed description of typical architecture for KBS may be found in work of Y. Power and P.A. Bahri [2005].

Expert system is very suitable for solving many problems in production management systems. A survey of the literature on expert systems for production planning and scheduling has been presented by Metaxiotis, Askoums, Psarras [2002]. The expert system is often an off-line system and is applied to the long-term management problem [Morimoto, Hatou, Hashimoto 1996]. For example, N. Karacapilidis, Adamides, Evangelou [2006] developed Co-MASS, a computerized knowledge management system for the collaborative development of manufacturing and operations strategy. An expert system for manufacturing systems machine selection has been proposed by H. Chtourou, Masmoudi, Maalej [2005]. A hybrid approach with an expert system and a genetic algorithm to production management in a node of supply network has been also developed by A. Ławrynowicz [2006]. R. Manzini et al. [2008] developed an integrated approach to the design and management of a supply chain system with an expert system. Besides, a knowledge-based system for strategic planning was developed by H.C. Huang [2009]. An intelligent and collaborative multi-agent system to generate and schedule production orders by using an expert system was proposed by O. López-Ortega, Lopez-Morales, Villar-Medina [2008]. Recently, an integrated approach to machine selection and operation allocation problem with expert system was developed by E.U. Guldogan [2011].

Genetic algorithm (GA) is a stochastic search method inspired by concepts from Darwinian evolution theory and belongs to a class of meta-heuristic methods [Tasan, Tunali 2008]. GA searches a problem space with a population of chromosomes and selects chromosomes for a continued search based on their performance. Each chromosome is decoded to form a solution in the problem space in the context of optimization problems. Genetic operators are applied to high performance structures (parents) in order to generate potentially fitter new structures (offspring). In general, the procedure of GA is as follows: (1) produce the first population chromosomes with a random method; (2) evaluate the fitness of the chromosome according to the measurement criteria; (3) create a mating pool by applying the selection operator; (4) create the offspring through crossover and mutation operators; and (5) if the best solution is obtained and meets the stop criteria, the program stops, otherwise, continue with step 3.

Genetic algorithms have many advantages over the traditional optimization methods. In particular, genetic algorithms do not require function derivatives and work on function evaluations alone; they have a better possibility of locating the global optimum because they search a population of points rather than a single point and they allow for consideration of design spaces consisting of a mix of continuous and discrete variables. Therefore, genetic algorithms have been successfully implemented to find good solutions to the various planning and scheduling problems. For example, K.J. Chen and P. Ji [2007] proposed a genetic algorithm for dynamic advanced planning and scheduling with frozen interval. Genetic algorithms have been also applied for job scheduling in distribution manufacturing systems. For example, F.T.S. Chan, S.H. Chung, P.L.Y. Chan [2005] proposed an optimization algorithm named Genetic Algorithm with Dominates Genes to solve distributed production scheduling problems with alternative production routings. H.Z. Jia, Y. Pu, Y. Ji [2007] proposed integration of genetic algorithm and Gantt chart for job shop scheduling in distributed manufacturing systems. Recently, many genetic algorithms have been developed for the multi-objective problem. For example, L. Dayou et al. [2009] considered an advanced planning and scheduling (APS) problem in manufacturing supply chain. To solve the APS model, a multiobjective genetic algorithm with local search is presented to find the Pareto optimal solutions. Currently, there is also a research trend in the adaptation of hybrid approaches which combine different concepts or components of various techniques. The trends have been presented by K.A.H. Kobbacy, S. Vadera, M.H. Rasmy [2007] in very interesting survey of applications of artificial intelligence techniques for operation management. A hybrid approaches to solving control problem in a node of supply networks has been published by A. Ławrynowicz [2008]. Beside, a hybrid evolutionary algorithm for the job shop scheduling problem is presented in the work by G.I. Zobolas, C.D. Tarantilis, and G. Ioannou [2009]. Summarizing, advances in artificial intelligence techniques create new prospects for cooperation in industrial clusters.

2. Integrated approach for modeling and optimization operations management

Many different approaches have been proposed for planning and scheduling problems in multi-factory environment. Generally, distributed scheduling problems deal with the assignment of jobs to suitable factories and determine their production scheduling accordingly [Chan, Chung, Chan 2005]. In the industrial cluster, multiple factories can be selected to manufacture the products. The factories may be located in geographically distributed location, but situated near (Figure 1). In this research, a typical industrial cluster, which has *J* different tasks (products) (1, 2, ..., *m*) for *F* factories (1, 2, …, *r*) is considered. Each factory has *R* resources (1, 2, ..., *q*). All jobs are loaded, according to the predetermined technological sequence given in processing plans. The routes for the jobs are such that a job may visit some resources and use some transportation more than once. There are several constraints on jobs and resources: (1) there are no precedence constraints among operations of different jobs; (2) operations cannot be interrupted and each resource can handle only one job at a time; (3) each job can be performed only on one resource at a time. In this approach, the processing plans of jobs can include also external transport operations. The objective is to minimize the total makespan of the industrial cluster.

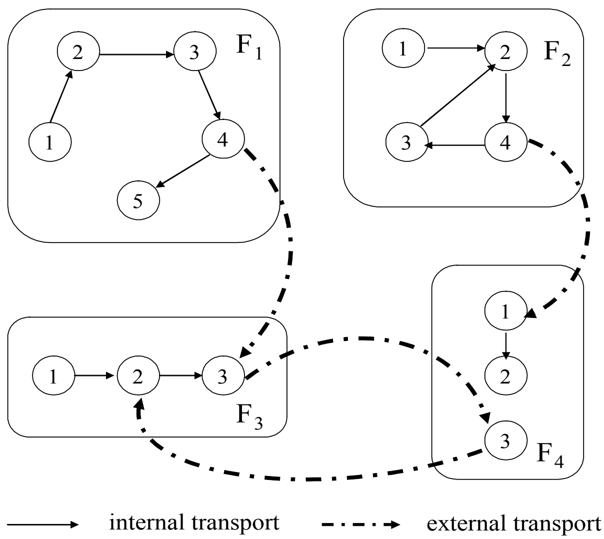

Figure 1. Relationships among jobs, resources, and factories in industrial cluster

From the mathematical point of view, Figure 1 shows a digraph which has loops and therefore the methods based on "network theory" cannot be easily adopted in supply network management. The main purpose of this research was to improve the efficiency of the traditional planning and control methods and explore a more effective and efficient approach to solving the same problem with the artificial intelligence. This research develops an expert system to create a production plan according to customer's orders and information from the industrial cluster and by using genetic algorithms to construct a schedule. Figure 2 shows the outline of the idea of planning and scheduling using an expert system and genetic algorithms. As shown in Figure 2, proposed hybrid system does not only offer short-term production planning and scheduling but also provides support for control. The first phase involves using traditional approach combined with the genetic algorithm to produce a preliminary and possibly suboptimal schedule. The second phase, a general approach to applying combinations of the expert system and the genetic algorithm in a industrial cluster is: using in the first phase expert systems to create a detailed production plan according to the customer's orders and reports from the cluster and using in the second phase genetic algorithms to construct a detailed schedule according to the detailed production plan. The hybrid system takes into consideration the jobs and generates detailed production plans based on available machines.

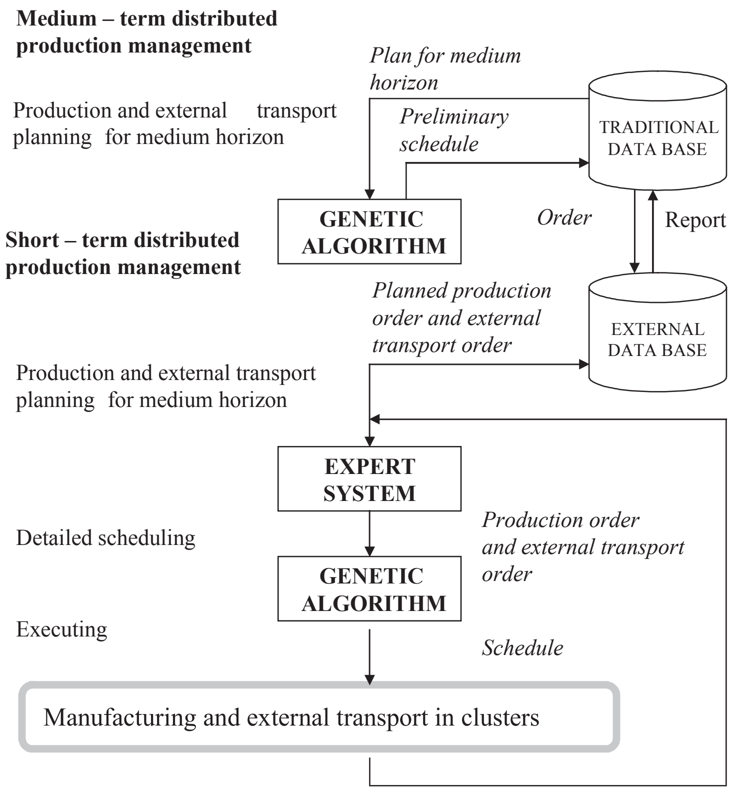

Figure 2. The outline of the idea of APRMC

3. Description of expert system

The proposed expert system is implemented in Prolog and uses its relational database and an external database for creation of the production orders and the transport orders. Orders are central to capacity planning. In this approach, the detailed production plan includes production orders and transport orders on a given time horizon. The production orders specify the work-piece and its lot-size, which are to be performed. In this approach, the work-piece is one job. Each work-piece (i.e. job) has a unique priority indicator according to the order of the customer. The job requires different types of production resources, that is, machines and transportation. All resources are available in a limited capacity only.

The expert system creating detailed production plans takes into account the planned production orders and work-in process from the report. The report includes scheduled operations, which cannot be performed. In such situations, both kinds of orders – the parts of the production orders (from the report) and whole planned production orders – are an input to the expert system (Figure 3). Detailed production planning matches future production load and capacities by generating detailed plans that determine the flow of materials and uses of resources over a given planning horizon. The expert system creates a detailed production plan as follows. The first step involves updating the planned production orders. In the second step, a human expert determines the top limit of priority indicator for orders. In the third step, a human expert selects *m*-th machine (bottleneck). Then the expert system automatically works out a sum of requirement capacity for *m*-th machine. After capacity requirement evaluation, the expert system compares the available capacity with capacity requirements. If the sum of requirement capacity is 70–100% of available capacity, then the expert system automatically creates a production plan from orders with a priority indicator smaller than or equal to the top limit indicator. In other cases, during an interactive dialogue a human expert makes a decision:

Is it possible to accept the sum of loads smaller than 70% of capacity of the machine?

Is it necessary to use an alternative processing plan or outsourcing?

Is division of lot-size possible?

The expert system will generate a production order according to the answers of the human expert. As shown in Figure 3, the proposed expert system with the external data base enables the analysis of bottlenecks and load balancing.

The benefit of the proposed intelligent methods is the possibility of incorporating proposed new systems into existing method such as MRP. In such situation, the expert system can be used as intelligent interface between the MRP – traditional data base – and the genetic algorithm which is presented further.

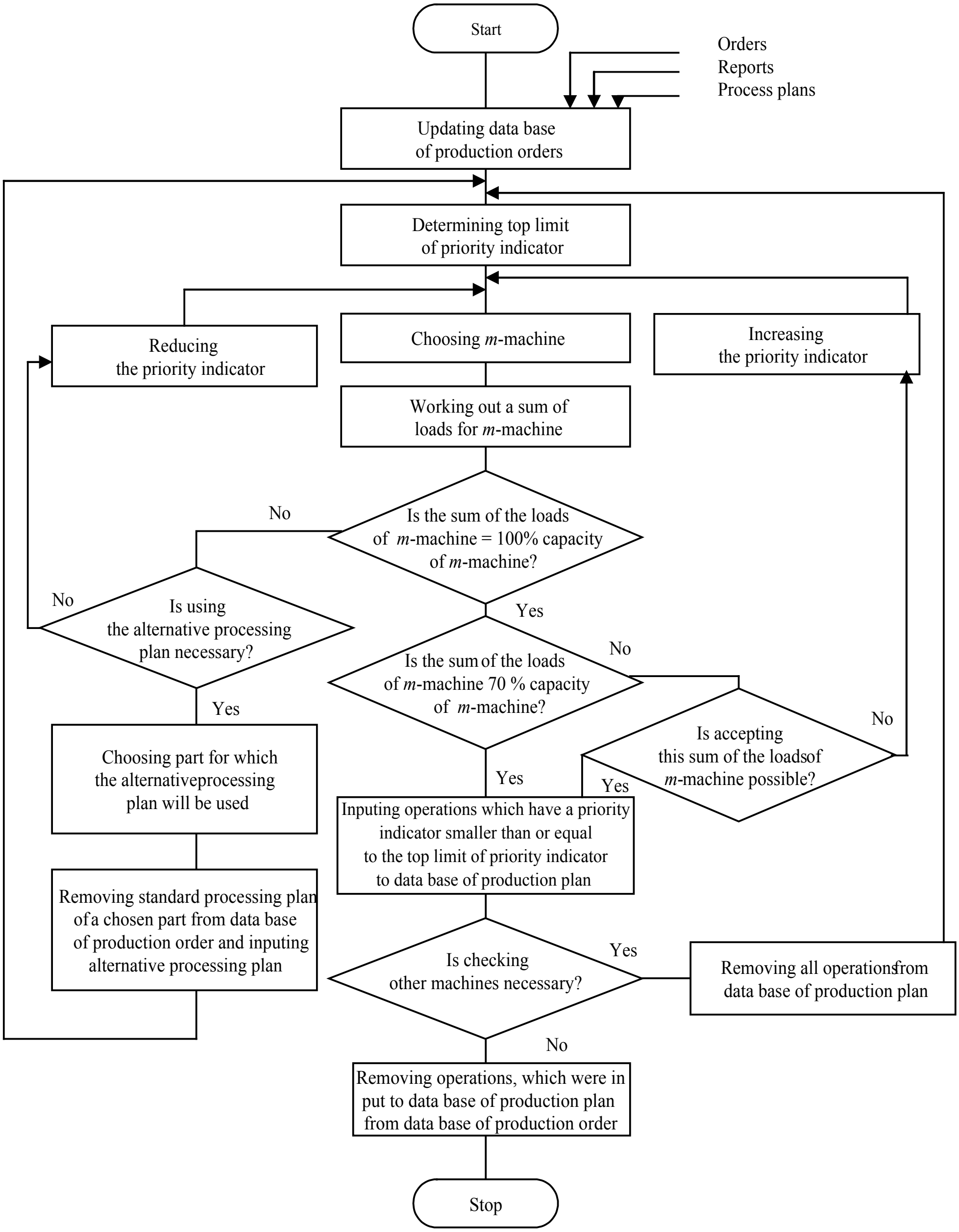

Figure 3. The general of the idea of creation of production plan with expert system

4. Scheduling in a cluster using a genetic algorithm

In ordering problem with the use of a genetic algorithm, the critical issue is developing a representation scheme to represent a feasible solution. Particularly, in the cluster where jobs will be dispatched to many factories, the encoding of the scheduling problems plays an important role to implement effective supply network management methods. In the scheduling problem, the popular encoding is operation-based method. This representation encodes a schedule as a sequence of operations and each gene stands for one operation. Basing on this idea, the author proposed new encoding method for a scheduling problem in the industrial cluster. In this approach, new genetic algorithm employs two steps to encode the scheduling problem. According to the step, two different types of chromosomes are designed. In the first step, each chromosome type A represents a potential optimal solution of a problem being optimized. The chromosome type A structure can be represented as a set of 4-positions genes where the value of the first position of the gene represents the job, the value of the second position the operation number, and the next two values the pair as follows: the resource number and the factory number or the transport order number and the source of the transport order number. The second step is to copy the first and the second position from the gene of the chromosome A into the gene of the chromosome B, and to translate the last two positions from the gene of the chromosome A into one position gene of the chromosome B. Chromosome type B is designed as follows. Similarly as chromosome type A, the first position represents the job, and the second the operation number, but the last position contains a unique number of the resource. In this approach, the initial population is created based on the chromosome type B. The procedure of the genetic algorithm can be illustrated as in Figure 4.

In this genetic algorithm, the well-known roulette wheel selector is used. The next population is created from the mating pool using the partial mapped crossover (PMX). Mutation is a random interchange of values in two positions. The detailed description of this genetic algorithm and its adjustment can be found in the work by A. Ławrynowicz [2009a, b, 2010a, b, 2011]. The results of the study with experiments showed that the proposed genetic algorithm is a very efficient and effective algorithm. The genetic algorithm creates the manufacturing schedule for each factory and transport operation schedule very quickly. The computational time for 97 operations was less than 4 minutes. Therefore, it can be applied in a dynamic setting when re-scheduling is initiated by disruptions and other unexpected changes. The results from the case study also indicated that the model is not only practicable but also beneficial for the transport decision making.

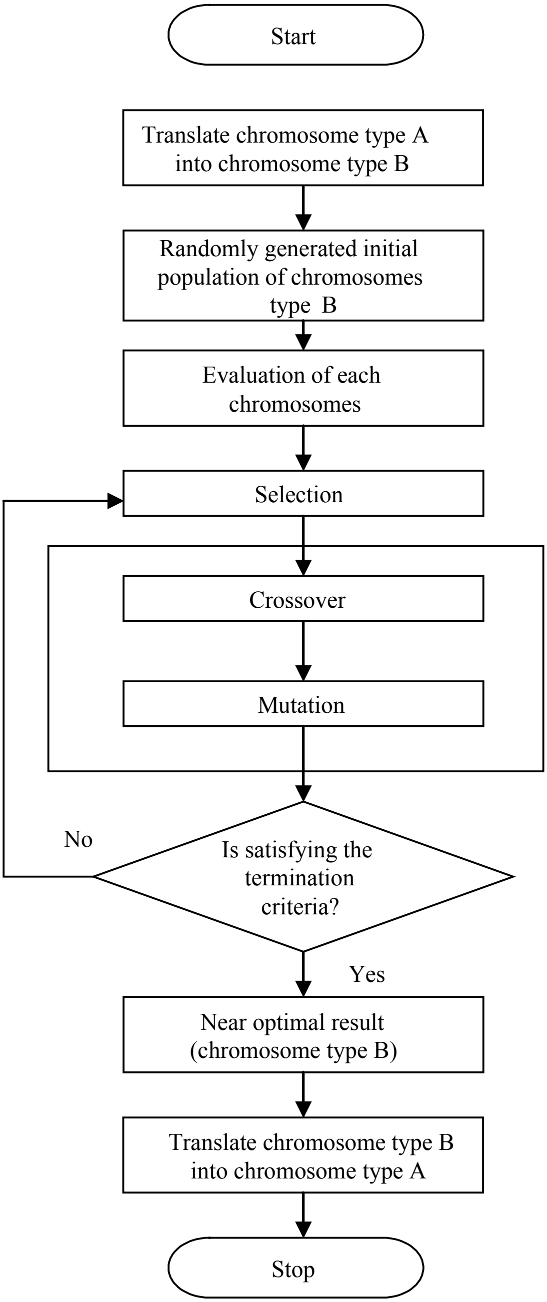

Figure 4. The procedure of the genetic algorithm

5. Conclusions

In the era of supply networks, decisions on the use of resources should concern both internal and external capacities; the internal flow of materials should be synchronized with the incoming and outgoing flows. A system for planning and scheduling must take into consideration the possibility of dividing jobs into factories, loops, and a long transport. Therefore, the main objectives of this approach were to produce an APRMC (Advanced Production Management in Cluster) model that minimizes the makespan by considering alternative machines, alternative sequences of operations with precedence constrains, and outsourcing. The approach is implemented as a combination of expert system and genetic algorithm. It does not only offer medium and short-term production planning and scheduling, but also provides a support for control. The proposed expert system and its external data base enables using alternative processing plan and outsourcing, thus it is possible to balance the capacity in the industrial cluster. The proposed genetic algorithm enables not only a manufacturing scheduling in supply networks. Additionally, the genetic algorithm aided planners in transport orders planning.

The benefit of the proposed intelligent methods is the possibility of incorporating proposed new systems into existing methods such as MRP. In such a situation, the expert system can be used as intelligent interface between the MRP and the genetic algorithm.

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PLANOWANIE I HARMONOGRAMOWANIE W KLASTRZE PRZEMYSŁOWYM Z KOMBINACJĄ SYSTEMU EKSPERCKIEGO I ALGORYTMU GENETYCZNEGO

Streszczenie: W referacie autorka proponuje innowacyjną metodę planowania i harmonogramowania w klastrze przemysłowym nazwaną APRMC (zaawansowane zarządzanie produkcją w klastrze). Podejście zostało zaimplementowane jako kombinacja systemu eksperckiego i algorytmu genetycznego. Pierwszy rozwiązywany jest problem planowania, a następnie harmonogramowania z uwzględnieniem ograniczeń rozwiązania. Badania adaptują algorytm genetyczny rozwijany przez A. Ławrynowicz.

Słowa kluczowe: klaster przemysłowy, system ekspercki, algorytm genetyczny.