Computers & Industrial Engineering 94 (2016) 63–73

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

Integration of process planning and scheduling using mobile-agent based approach in a networked manufacturing environment

Vijaya Kumar Manupati [a,*], Goran D. Putnik [c], Manoj Kumar Tiwari [b], Paulo Ávila [d], Maria Manuela Cruz-Cunha [e]

[a] *School of Mechanical Engineering, Department of Manufacturing, VIT University, Vellore, Tamil Nadu 632014, India*
[b] *Department of Industrial and Systems Engineering, Indian Institute of Technology Kharagpur, Kharagpur 721302, West Bengal, India*
[c] *Department of Production and Systems Engineering & ALGORITHMI Research Centre, University of Minho, 4800-058 Guimarães, Portugal*
[d] *CIDEM, School of Engineering, Polytechnic of Porto, Portugal*
[e] *Polytechnic Institute of Cavado and Ave, Portugal*

ARTICLE INFO

Article history:
Received 27 November 2014
Received in revised form 14 December 2015
Accepted 22 January 2016
Available online 6 February 2016

Keywords:
Mobile-agent
Networked manufacturing
Ontology
Process planning
Scheduling

ABSTRACT

Effective and efficient implementation of intelligent and/or recently emerged networked manufacturing systems require an enterprise level integration. The networked manufacturing offers several advantages in the current competitive atmosphere by way to reduce, by shortening manufacturing cycle time and maintaining the production flexibility thereby achieving several feasible process plans. The first step in this direction is to integrate manufacturing functions such as process planning and scheduling for multi-jobs in a network based manufacturing system. It is difficult to determine a proper plan that meets conflicting objectives simultaneously. This paper describes a mobile-agent based negotiation approach to integrate manufacturing functions in a distributed manner; and its fundamental framework and functions are presented. Moreover, ontology has been constructed by using the Protégé software which possesses the flexibility to convert knowledge into Extensible Markup Language (XML) schema of Web Ontology Language (OWL) documents. The generated XML schemas have been used to transfer information throughout the manufacturing network for the intelligent interoperable integration of product data models and manufacturing resources. To validate the feasibility of the proposed approach, an illustrative example along with varied production environments that includes production demand fluctuations is presented and compared the proposed approach performance and its effectiveness with evolutionary algorithm based Hybrid Dynamic-DNA (HD-DNA) algorithm. The results show that the proposed scheme is very effective and reasonably acceptable for integration of manufacturing functions.

1. Introduction

Global competition renders adequate return on investment only to those who can provide innovative and intricate products having high quality, with less process iterations and more cost competitiveness. The existing manufacturing systems cannot adequately conform to these requirements because of their deterministic approach to decision-making in an uncertain environment. In order to respond to rapidly changing environment and to obtain high product variety and short product life cycles, a shift of the manufacturing paradigm from deterministic to a dynamic adaptive control of a manufacturing system is indispensable. Several next generation manufacturing systems are emerging, such as the Bionic manufacturing system (Okino, 1993; Ueda, 1993), the Fractal factory (Warnecke, 1993), Holonic manufacturing system Valckenaers et al. (1994), and Distributed manufacturing systems (Peklenik & Jerele, 1992), that are adaptable to environmental changes, particularly when market demands cause frequent turbulent fluctuations. Over the past few years much research and study (Rosenau, 1996; Wang, 1997; Wilde & Briscoe, 2011), have proven that distributed manufacturing system enables the enterprises to enhance the flexibility and re-configurability for achieving better quality and cost effective manufacturing strategies. Recently emerged networked manufacturing or network based manufacturing paradigm is one such distributed manufacturing system which can support the above mentioned requirements and their functionalities.

* Corresponding author. Mobile: +91 9775627564.
E-mail addresses: manupativijay@gmail.com, manupati.vijay@vit.ac.in (V.K. Manupati), putnikgd@dps.uminho.pt (G.D. Putnik), mkt09@hotmail.com (M.K. Tiwari), patg@math.uminho.pt (P. Ávila), mcunha@ipca.pt (M.M. Cruz-Cunha).

http://dx.doi.org/10.1016/j.cie.2016.01.017
0360-8352/

Networked manufacturing enables the circulation and integration of information and knowledge from product design to manufacturing and enables resource sharing between geographically distributed enterprises, thus endowing enterprises with the ability to quickly respond to the market (Yan, 2000). In networked manufacturing, the mode of production has been changed from make-to-stock to make-to-order, in which the active participation of customers submitting jobs to the manufacturing system is emphasized. The concept of improving productivity and competition of delivery times between different manufacturing jobs is becoming a focal point for enterprises to survive in the current global market. In order to achieve them, obtaining an optimal or near optimal process plans for manufacturing multiple jobs is becoming a critical problem.

Process planning specifies which tasks (operations, controls, transports and stores), their interdependence and the resources to perform them. The scheduling is the allocation of resources in the shop over a planning horizon to manufacture the various parts (Zhang, Saravanan, & Fuh, 2003). Optimality of process plan and production schedule often conflict under traditional planning methods. In the traditional manufacturing system, the manufacturing functions were carried out in a sequential manner, where scheduling was done after process plans had been generated. Therefore, it is possible that the process plans generated were not optimal from scheduling point of view (Bratoukhine, Sauter, Peschke, Luder, & Klostermeyer, 2003; Cheng, Proctor, Michaloski, & Shackleford, 2001; Wada & Okada, 2002). The difficulties in traditional manufacturing approach and the obstacles to improve the productivity and responsiveness of the manufacturing systems have been clearly stated (Saygin & Kilic, 1999).

To overcome the above mentioned problems in traditional manufacturing approach, integration methods have been proposed to resolve the dilemmas in manufacturing functions. In Chryssolouris and Chan (1985) and Chryssolouris, Chan, and Cobb (1984), the basic idea of process planning and production scheduling has been introduced. Till date many methods and approaches have been developed for improving the flexibility of the integration approach on manufacturing systems for obtaining better performance of the system (Manupati, Sujay, Cheikhrouhou, & Tiwari, 2012). In recent years, much attention toward agent/multi-agent based approach has been shown by many researchers for integrating the manufacturing functions, particularly in distributed environment. "Agent can be defined as a system encapsulating software that communicates and collaborates with other software systems to resolve the complex problems that are beyond the capability of each individual software system" (Wang, Shen, & Hao, 2006). In Li and Chaoyong (2010), authors have provided a detailed literature review on Integration of Process Planning and Scheduling (IPPS), particularly on agent based approach and its advantages over distributed manufacturing systems. A comparative study has proved that agent/multi-agent systems are well suited for dynamic manufacturing scheduling due to their flexibility, modularity, autonomy, robustness and heterogeneity (Ouelhadj & Petrovic, 2009).

The mobile agent based approach in a distributed manufacturing environment (Meng, Ren, Cao, & You, 2011) is different from the above mentioned agent and multi-agent systems. In addition to having all the features of agent and multi-agent systems, it also has some additional characteristics such as mobility which helps to transport the messages throughout the network (Meng et al., 2011). Thus, the mobile agent has leverage over other classes of agents and its approach can be effectively deployed to execute new control algorithms for performing tasks of any sub system in a network (Nestinger, Chen, & Cheng, 2010). Lange and Oshima (1998) revealed several distinctive reasons by using a mobile agent approach and also found its ability to travel through the network; hence it reduces the network load, overcomes network latency, increases the ability to encapsulate protocols and executes asynchronously and autonomously. Developing negotiation procedure based contract net protocol has been a pioneering work in the area of distributed manufacturing systems which can enhance the information exchange between autonomous agents (Smith, 1980; Smith & Davis, 1981). Different negotiation mechanisms (Baker, 1991; Butler & Ohtsubo, 1992; Lin & Solberg, 1992), have been developed to enhance the efficient flow of information to pursue the system goals. However, from the summary of findings, we have concluded that there is still a need for an efficient negotiation mechanism which can maintain the standard for communication among the agents.

In the present research, we have first developed a mathematical model along with constraints and then presented a framework of mobile-agent based negotiation schemes for integrating process planning and scheduling in a networked based manufacturing environment. An illustrative example along with complex scenarios is presented to demonstrate the effectiveness of the proposed method. Moreover, with an evolutionary algorithm based effective hybrid DNA algorithm (Manupati et al., 2012) the results has been compared. Results show that the proposed approach performed significantly good.

In Section 2, we have provided the detailed description of a problem and its basic assumptions, later we also developed a mathematical model along with the constraints. In Section 3, we presented a framework of mobile agent based negotiation scheme to integrate the process planning and scheduling functions. Section 4 explains the mapping of negotiation based schedule scheme. The experimentation with an illustrative example having different complex scenarios is illustrated and the results are presented in Section 5. In Section 6, the results and their discussions are detailed. Finally, conclusions are drawn and future work delineated.

2. Multi-objective problem description

We consider a series of jobs ordered by different customers and denote it by n. Each job out of series of jobs has its alternative process plans for efficient use of production resources which leads to better delivery schedules. Here, each process plan contains series of sequential operations where each operation corresponds to set of alternative machines. In broad sense, each operation has its alternative process plans. However, in networked manufacturing environment, the number of machines related to jobs are geographically distributed to perform different operations on the jobs. The above mentioned problem is further extended by increasing the number of products with inclusion of product mix and production demand fluctuations. This extension in the problem leads to much larger search space and thus the problem becomes complex to solve. Finding out the optimal/near optimal solutions from such a huge search space in a reasonable environment is quite difficult. Networked manufacturing has flexibility to integrate with distributed manufacturing tools (agent/multi/mobile agents) to generate the feasible process plans.

In order to satisfy the above mentioned problem and its objective function effectively and efficiently, several assumptions and constraints are described as follows: (1) job pre-emption is not allowed; (2) a job cannot be processed on a machine until its predecessor job gets finished; (3) each machine can handle only one job at a time; (4) transportation time of the machines is considered. Where the manufacturing system is designed in such a way that after an immediate completion of the operation of a job on a machine, it is immediately transported to the succeeding machine