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Investigation of reconfiguration effect on makespan with social network method for flexible job shop scheduling problem

M.B.S. Sreekara Reddy [a], C.h. Ratnam [a], Rajeev Agrawal [b], M.L.R. Varela [c], Ila Sharma [d], V.K. Manupati [d,*]

[a] Department of Mechanical Engineering, AUCE, Visakha Patnam, AP, India
[b] Department of Production Engineering, Birla Institute of Technology, Ranchi, India
[c] Department of Production and Systems, School of Engineering, University of Minho, Portugal
[d] School of Mechanical Engineering, VIT University, Vellore, Tamil Nadu, India

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ABSTRACT

This paper presents a novel social network analysis based method (SNAM) to evaluate the reconfiguration effect i.e., identification of key machines and their influence on the system performance in the context of Flexible job shop scheduling problem (FJSSP). This research formulates a mathematical model along with the constraints by incorporating the total completion time of jobs as an objective function. The proposed SNAM has been applied to generate the collaboration networks by transforming the input data and presenting them in the form of an affiliation matrix to the network analysis software. Thereafter, to analyze the collaboration networks various SNA measures that have been calculated and different functional properties are evaluated. Finally, to investigate the reconfiguration effect on makespan integration of process planning and scheduling (IPPS) has been implemented with adopted effective game theory based hybrid deoxyribonucleic acid (DNA) algorithm. The validation of the proposed approach and its effectiveness is conducted through comparisons with benchmark instances and results confirm the efficiency of the proposed approach.

1. Introduction

The current manufacturing sector needs to change its trend and scale new heights by inculcating the recent advancements in technology that has created the need for customized products among customers leading to high degree of competition between industries. To cater the mentioned requirements, particularly in a shop floor scenario, it is crucial to choose efficacious manufacturing strategies that can schedule effectively and efficiently to enhance the firm's productivity. In recent years, researchers are trying to achieve an optimum as well as a feasible schedule, which can able to perform an operation on more than one machine out of set of machines.

In our paper, we are focussing on Flexible Job Shop Scheduling Problem (FJSSP), which is an extension of the classical JSSP. The FJSSP, as the name suggests, is able to adopt a more flexible setup where it is feasible to run an operation on more than one machine. Hence, in FJSSP, it is very difficult to identify the allocation of operations on a particular machine out of a set of competent machines. Additionally, monitoring the sequence of operations in order to minimize the makespan is a cumbersome task which makes it more arduous than JSSP. From the literature, job shop scheduling problem has been validated as a NP-hard problem Garey, Johnson, and Sethi (1976) and it can be concluded that FJSSP is a NP-hard combinatorial optimization problem.

In general, FJSSPs have been solved by two different approaches: Hierarchical and Integrated approaches Zhang, Gao, and Shi (2011). In Hierarchical or the traditional approach, process planning and scheduling has been regulated in a successive manner. In other words, to solve the problem with hierarchical approach, divide the problem into sub-problems and then solve it individually Brandimarte (1993). The greatest risk associated with this approach is the chance of losing out on high quality favourable solutions and settling with a compromising solution for both objectives. Saygin and Kilic (1999) mentioned various difficulties with traditional/hierarchical approach and the related obstacles to be settled in order to improve the productivity of the system. Numerous approaches for solving the FJSSP were proposed by Hurink, Jurisch, and Thole (1994); and Najid, Dauzere-Peres, and Zaidat (2002). Yang (2001) introduced the multistage genetic algorithm to solve the FJSSP for improving the performance measures of the system. Tay and Ho (2008) combined different dis-

* Corresponding author.
E-mail addresses: mbssreddy@kluniversity.in (M.B.S. Sreekara Reddy), chratnam@gmail.com (C.h. Ratnam), manupativijay@gmail.com (V.K. Manupati).

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patching rules as composite rules for solving the multi-objective FJSSP by improving the objective functions such as minimization of makespan, mean tardiness, and mean flow time. With sensitivity analysis the validation of the presented rules has been established and the robustness of the proposed approach is examined. Wang, Wang, Xu, Zhou, and Liu (2011) presented the bi-population based estimation of distribution algorithm to solve the FJSSP. Using the Taguchi tools, the parameters have been examined and then the favourable ones are identified. Using these identified parameters the algorithm performance has been examined and the best performance is realized.

Coello (1999) presents a critical review on the evolutionary based multi-objective optimization techniques and described various advantages and disadvantages with some of the know applications. Fonseca and Fleming (1995) reviewed multi-objective optimization evolutionary algorithm approaches ranging from the conventional analytical objectives into a single function to a number of population-based approaches. Tayebi Araghi, Jolai, and Rabiee (2014) proposed the genetic variable neighbourhood search along with affinity algorithm to optimize maximum completion of jobs in the context of FJSSP. Along with the Taguchi based approach the algorithm parameters are tuned to their best values and in different experimental setups the experimentation has been conducted. By statistical analysis the effectiveness of the algorithm has been demonstrated and proven. Zhao, Zhang, Wang, and Zhang (2014) introduced an improved shuffled complex algorithm with opposition based learning for a permutation flow shop scheduling problem to optimize the key performance measure i.e., makespan. Zhao, Jiang, Zhang, and Wang (2015) proposed chemotaxis enhanced bacteria foraging algorithm to solve the tumble failure problem in tumble step and then with different job shop scheduling instances the performance of the algorithm has been tested and proved its efficiency. Türkyılmaz and Bulkan (2015) developed a hybridization algorithm by integrating genetic algorithm with variable neighbourhood search algorithm at the sophisticated selection phase of the genetic algorithm to solve the flexible job shop scheduling problem by minimizing the total tardiness of the system.

Motivation drawn from the fact that over the past few years, research and study Wu and Xia (2005), Zhang, Shao, Li, and Gao (2010), Bagheri and Zandieh (2011), and Ulungu, Teghem, Fortemps, and Tuyttens (1999) have been done by many researchers and they have focused on different hybrid evolutionary algorithms to solve the multi-objective FJSSP. Although many approaches and models have been constructed in the recent past, we have identified that there persists a need to address certain issues of the newly emerged manufacturing systems such as FJSSP. The network structure has negligible effect on the performance of the manufacturing system. A network diagram is a visual representation of the interaction of the various elements from which we derive flexible characteristics of a job among the process plans. This research primarily focuses on responding the following questions:

(1) How are the network diagrams from SNAM relevant to our work and how the relationships in the network involved in influence the system performance?
(2) What are the effects of the proposed social network analysis method on the considered FJSSP, and how these effects influence the considered objectives i.e., makespan and the computational time?
(3) How do different centrality measures affect the system configuration and how do these measures help to identify the key machines/hubs which are randomly used for processing the jobs on machines till date?

SNAM allows calculating measures and drawing graphs that describe and illustrate the individual and collective structure of a network (Fidalgo & Thormann, 2012). The main measures calculated in SNA are centrality measures. Centrality measures identify the most prominent actors, i.e. those extensively involved in relationships with other network members (Freeman, Roeder, & Mulholland, 1979). The most commonly used centrality measures are: (i) degree centrality; (ii) betweenness centrality; and (iii) closeness centrality; Degree centrality corresponds to the number of actors with whom a particular actor is directly related (Borgatti, 1995). Betweenness centrality represents the number of times an actor connects pairs of other actors (Bonacich, 2007). With closeness centrality, it is possible to know how closely actors are connected to the entire social network (Opsahl, Agneessens, & Skvoretz, 2010). Despite the tremendous capabilities of SNAM on addressing a wide range of problems varying from natural phenomena (Lu & Hamilton, 1991; Neukum & Ivanov, 1994, and Crovella & Bestavros, 1996), military (Roberts & Turcotte, 1998), World Wide Web (Adamic & Huberman, 2000), etc. very limited work has been done in the domain of social network analysis of manufacturing problems in contrast to networked manufacturing problems.

In the FJSSP the machines performance has been considered as one of the important parameter among many other parameters. In this research work, our main objective is to improve the performance of the system by maximizing the total completion time of the jobs. To achieve this, identification of key machines in the system is an important task. However, till date in the literature the key machines in any manufacturing systems are taken as random while performing the scheduling. In this research study, with the proposed social network approach reconfiguration of machines i.e., by adding and removing of machines how the performance in the system can be effect has been examined. Moreover, with this approach the highly influencing machines out of key machines for the considered system has been identified to achieve the desired objective.

In this paper, with SNAM approach the flexibility of self-contained structure in collaboration networks, the cohesive sub-networks (for identification of the autonomous work systems) and its descriptive statistics are collectively used to analyze the performance of the system (Wasserman & Faust, 1994) is obtained. Moreover, in FJSSP, the size, scope and complexity of the network is not defined whereas in SNAM, a clearer representation of the functional properties, such as centrality measures, network complexity and the network size is probable (Newman, 2005). The SNAM theory considers three basic elements (see e.g. (Barabási et al., 2002; Hawe, Webster, & Shiell, 2004)): (i) Actors – network members that can be distinct individuals or collective units; (ii) Ties – link actors within a network; and (iii) Graphs – visual representation of the networks where nodes acts as the actors and the ties as lines. Additionally, there is sparse information of the communication flow within the network structure and the descriptive statistics that can be used to extract some information about the speed or nature of the structure. In this research work, SNAM played a crucial role in identifying the key machines by making the entire process facile unlike the process of simulating the reconfiguration effect that involves step by step elimination of every machine from the system, change in various parameters, reprogramming of the software at every step of reconfiguration effect and interpretation of the result after the simulation is complete. To our knowledge, real-time event, such as machine breakdown, in FJSSP is difficult to express and no profound study has been invested in it. Thus, we have translated this research work to examine the system's behaviour when real event occurs and how