Multi Agents approach for Job Shop Scheduling Problem using Genetic Algorithm and Variable Neighborhood Search method

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ABSTRACT

The job shop scheduling is an important and complex problem for a manufacturing system. It is well known and popular problem having (Non-Polynomial) NP-hard characteristic to find the optimal or near optimal solution (schedules) quickly. In job shop scheduling a set of “N” number of jobs are processed through an “M” number of given set of machines. It must be processed in the prescribed order by utilizing the feasible sequence of operations for a job. Therefore, due to its complex nature the finding of approximate solutions are chosen rather than the finding exact solution which involve higher cost. Various meta-heuristics techniques are utilized in order to find the sub-optimal solution for job shop scheduling problem. Genetic Algorithm (GA) and Variable Neighborhood Search (VNS) method are the preferred techniques which are best-known for global and local search of solutions respectively. VNS is work as in augment for GA approach. In the present work, Multi-agents are proposed to find the near optimal solution for job shop scheduling problem using GA and VNS approach in parallel. Multi-agent system is preferred owing to its ability to perform in parallel and robustness as well as the elucidation of intelligence. In the proposed system, many hosts of the network are accommodated with agents. JADE is used to setup communications. Each agents is designed to perform the specific task namely Initialization Agent (IA), Processing Agent (PA) and Coordinating Agent (CA) for initial generation of population, to schedule the operations on machines, to find the distinctive host and to perform the migrations between various populations respectively. The objective is to find an optimal value of makespan for the job shop scheduling problem. The performance of the system is assessed by a case study and it reveals that the proposed approach is effective enough to find the optimal solution. Future works is to introduce Disturbance Agents (DA) for internal and external disruptions.

Keywords: Multi Agents Systems, Job shop Scheduling, Genetic Algorithm, Variable Neighborhood Search, Makespan

1. INTRODUCTION

Today’s manufacturing houses are under huge pressures in order to react in swiftly and vigorously changing demand of products and fluctuating product mix. The conventional approach of manufacturing environment working in consecutive phases of designing, building and setup of production systems at the preparation stage to planning, scheduling and control of production at the operational stage, is challenging in filling the conditions of the fluctuations[1-2]. The efficiency as well as the productivity of the manufacturing system can be only improved through the well-organized and real-world approach for optimization process of scheduling. The conventional approach for optimization of scheduling problem is constantly pact through the strong schedule of static operation time whereas as in real handling problems, there may be various factors with uncertainty such as change in the operation time, demand of products, delivery of orders, failure of machineries and differences in the production. Thus, these actively interfering factors results in interruptions to implement original schedules. Consequently, rescheduling or adaptive approaches are prominent for dynamic scheduling [1, 3-4].

In production scheduling, the job shop layout can be termed as a problem of real-world to perform scheduling. In advanced struggling marketplace having condition environment of lessor product cost and smaller cycle of product life, every industry is bound for rapid reactions in order to satisfy the customers’ demands. To achieves this edition, production scheduling function act as a cardinal part. In job shop scheduling a set of “N” number of jobs are processed through an “M” number of given set of machines. It must be processed in the prescribed order by utilizing the feasible sequence of operations for a job. The processing time consumed to execute each operation of all jobs is termed as makespan. Hence, the ultimate target for the job shop scheduling problem is to decrease the value of makespan. It is well known and popular problem having NP-hard (Non-Polynomial) characteristic to find the optimal or near optimal solution (schedules) quickly [5].

It is well-known that Meta-heuristics approaches are extensively applied in order to find the solutions for the practical problems of optimization. During last decades, a large number of algorithms have been developed in order to solve the job shop scheduling viz., Genetic Algorithm, Particle Swarm Optimization, Ant Colony Optimization, Artificial Bee Colony, and Bee Colony Optimization. Literature reveals that Genetic Algorithm has been used widely for every type of scheduling problems as well as for specifically for job shop scheduling problem. Various studies reveals that the performance of the Genetic Algorithm can be improved significantly through hybridization with other nature inspired heuristic algorithms and also using these approaches in parallel [6-8].

Researchers discovered parallel Genetic Algorithm approach in 1980s and 1990s and practices the Genetic Algorithm on parallel computers in order to create this approach much quicker. Parallel Genetic Algorithm approach may be categories as follows. a) Master-slaver Model, b) Coarse-grained, c) Fine-grained, d) Hybrid algorithm [9]. These approaches have been
applied by various researchers for job shop as well as other production scheduling problems.

A grid based job scheduling problem using Coarse-grained parallel Genetic Algorithm to minimize the makespan and job processing time presented by Zhang and Chen [10]. They compared the proposed approach with regular process and find the better level of utilization of resources. Kirley [11] presented the parallel approach for solutions in fractions through separating job shop scheduling problem in subsets of problems in order to reduce the level of complexity. Asadzadeh and Zamanifar [12] suggested parallel approach with genetic algorithm based on coarse-grained model with multi-agents system. Sub-populations were created and opening set of population was distributed accordingly. The relocation of genes and chromosomes were responsible to setup the communication among sub set of population. A coarse-grain genetic algorithms associated in a fine-grain style topology proposed by Lin et al. [13]. They stated that the proposed system can escape from premature convergence as well as very good results were obtained over testing on benchmark problems of job shop scheduling.

Hybrid genetic algorithm approaches is very common arrangement in which pairing of genetic algorithm with problem-fixed techniques to enhance the effectiveness of the methodology. Some conventional heuristic procedures are coupled in order to improve the performance of solution search. In literature, various researchers have provided the survey of latest contributions for the job shop scheduling problem implemented with different mix approaches of the genetic algorithm. A local search Genetic Algorithm is proposed by Ombuki and Ventresca [14]. They considered a well-organized representation scheme for solutions, which was capable to eliminate repair operation as well as efficient to check the constraints effectively. At the stage of local search, a new type of mutation operation was applied for solution excellence. Wang and Zheng [15] proposed a hybrid Simulated Annealing and Genetic Algorithm approach for job shop scheduling which works in parallel. They developed problem-specific operators and encoding strategy and solved benchmark problems individually as well as through the proposed hybrid approach.

In the present work, both the strategies of hybridization and parallelization have been considered in order to improve the performance of Genetic Algorithm and developed a multi-agent based local search strategy in parallel with Genetic Algorithm to provide the optimal solution for job shop scheduling problem. A parallel search Genetic Algorithm is proposed in which multi-agents performs individual actions.

Sections 2 of this paper presents the developed approach of agent based for job shop scheduling in brief. The construction of proposed model is described in section 3. Parallel local search genetic algorithm is discussed in details in section 4. Results and conclusions are given in sections 5 and 6 respectively.

2. ADOPTED METHODOLOGY

In the last decade, extra concentration is perceived on the research findings for parallel Genetic Algorithm in order to solve the hard problems. These problems are associated with a vast domain of populations (search space) which requires greater power for computation work. The coarse grained parallel Genetic Algorithm has been proved as a well-known approach which is capable to segment the population in smaller set of populations. In this model, the approach of polarization is capable to host an additional operator in addition to regular Genetic Algorithm. This operator direct the individuals from one segment of population to another segment. It is termed as migration operator. In the present work, island model strategy is used in which geographical separation and relocation is established in between neighbor islands or set of populations (subpopulation). In this scheme, various quarantined set of populations grow in parallel to each other. Moreover, every island perform individual genetic operators and share the fittest individual time to time using the mechanism for relocation (migration).

In case of highly complex problems, Genetic Algorithm clubbed with various other methods associated with specifications and structure of the problem to be solved effectively. Integration of local search method with Genetic Algorithm has been proved as a successful strategy in order to produce the optimal solutions. In this hybrid scheme, in each iteration of Genetic Algorithm a local search operation is executed on the individuals separately. This approach is preferred to yield robust solutions as compare to distinct algorithms.

Parallel and distributed approaches have considered multi agents based systems for a large number of problems. This system is known due to its central role of agents having the ability to implement the parallel search in Genetic Algorithm. In the present work, this feature has been employed to solve the job shop scheduling problem and few agents have been planned logically.

3. CONSTRUCTION OF PROPOSED MODEL

JADE [16] platform is used to implement the designed multi agent model and executed various agents. JADE platform is known for the development of a software evolving multi agent structure. This middleware assists for agents building and setup their message transitory. The bottom most layer of the proposed construction is the peer-to-peer communication network of computers which provides settings for implementation and development of the model. This network permits each agent to regularly determine the other agents to setup the interconnection. Figure 1 illustrates various operational layers of proposed multi agent model.

![Figure 1: Adopted operational layers for multi agent model](image)
All agents are scattered over the hosts of the network. Agent communication channel outfit on JADE for safe communication. Each agent have a designed function to be perform.

Initialization Agent (IA) creates initial population randomly for Genetic Algorithm as well as this agent is responsible to calculate the fitness function value of individuals. Moreover, main host holds IA and the performance of the other agents is govern over the whole platform. In addition, individual Processing Agent (PA) works over the different hosts and accomplish Genetic Algorithm on the sub sets of populations. The Coordinating Agent (CA) is designed to localize on the main host as well as it is responsible for synchronize the function of relocation of population through PA agents. Figure 2 illustrate the adopted multi agent structure for job shop scheduling problem.

**4. PARALLEL GENETIC ALGORITHM APPROACH**

In the present work, Genetic Algorithm is linked-up with the local search method in order to enhance the effectiveness and performance of parallel search strategy. In this approach, an individual operator has been executed over the whole population during every generation. Therefore, this crossbreeding approach is capable to yield better results as compare to the distinct approaches. It is important to mention here that in the present work the algorithm given in Asadzadeh [17] has been utilized. In which, once the Genetic Algorithm and job shop scheduling parameters are laden, the populations is generated by the IA agent and calculate the value of fitness for each solution. Once the fitness values are evaluated for whole population, IA agent splits the population into sub set of populations with balanced size and transfer them to PA agent. This agent traces on different hosts and performs Genetic Algorithm on the sub set of populations autonomously. The communication is setup by the help of trading of migrants (relocations). This approach have two stages viz., evaluation stage and migration stage. In earlier, various agents’ works separately on the individual sub set of populations, in the later stage, migrants are exchanged. These stages works in iterative and interactive manner.

**Variable Neighboring Search**

Once the crossover operator is applied PA agent executed in order to enhance the fitness of newly generated chromosomes. Variable Neighborhood Search is applied to explore the local search. This algorithm is proposed by Asadzadeh [17]. In this search method, there are two types of mutation operations viz., Exchange and Insert. These operators performs on randomly chosen individuals and finally the best individual is picked by comparing with earlier fitness value.

**Mechanism for Relocation**

The sub sets of populations are interconnects to each other through the migration exchange. In this work, a synchronous migration strategy is used as suggested by Asadzadeh [17]. In which PA performs the local search algorithm for a specific number of iterations and dispatch to CA agent in order to inform the completion of the evaluation stage. CA agent harmonies the migration in between the PA sub sets of population. Once the information gathered from every PA agent, the CA agent executed in order to program them for migration stage. In this stage, PA agents setup the communication to exchange few of better individuals within neighbor. The solutions having poor fitness are replaced with better fitness individuals.

**5. IMPLEMENTATION**

In this section, the detailed implementation of proposed approach such as representation of chromosome, evaluation of fitness function, selection scheme and operators have been presented.

**Chromosome Representation**

The feasible solutions of job shop scheduling problem are encoded by chromosomes. Coding of solution is very important aspect for Genetic Algorithm effectiveness. It parameters included in the coding decides the amount of search space to be explore. The solution (schedule) can be represented in two categories viz., Direct and Indirect representations. In the present work, direct scheme of schedule representation has been adopted. In which, each operation number of particular part contains identical code (figures). The sequence of codes in an individual (chromosome) explains the encoded solution of schedule. In a job shop scheduling problem, there are “N” number of parts and “M” number of machines i.e. NxM number of genes of chromosomes. Table 1 shows the job shop problem having 3 number of parts and 3 number of machines. Thus, the sample chromosome representation using direct scheme for this problem can be written as C B C A B A B A C. In which, C represents part-C, and part-C have 3 number of operations consequently, its existence is three times in the encoded chromosome. Moreover, the order of existence of C is equivalent to the order of operation to be executed for part-C. In other words, the number of presence times of the parts in the chromosome is equal to the number of its operations “K”. It is very clearly that any fixed and random sequence of gene yields a feasible solution in terms of schedule [4]. A standard and regular process of initialization of Genetic Algorithm has been adopted in the present work.

The optimal value of makespan for the present case study is 24 units and the corresponding chromosome is: C B C C A B A B A. It can be encoded in terms of machines and processing time as machine number (processing time): (1-4)- (1-8)-(3-2)- (1-5)- (3-2)-(2-5)-(1-5)-(3-2)-(2-2). Figure 3 shows the Gantt chart of the taken example.

Table 1: A sample case study of 3 parts & 3 machines job shop

<table>
<thead>
<tr>
<th>Parts No.</th>
<th>Machine Number, (Operation Time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2(5) 1(5) 3(2)</td>
</tr>
<tr>
<td>B</td>
<td>2(8) 3(2) 2(5)</td>
</tr>
<tr>
<td>C</td>
<td>2(4) 3(3) 1(2)</td>
</tr>
</tbody>
</table>
Genetic Operators

The fitness value of the chromosomes are determined using the fitness function proposed by Goldberg [18]. In which, fitness function given as: \( F(x) = M_{\text{max}} - M(x) \), Where, \( F(x) \) is the fitness value of a chromosome having makespan value of \( M(x) \) and \( M_{\text{max}} \) is the maximum value of makespan of an individual in the population. In the present work, Roulette wheel selection scheme is utilized to select the individuals from the population. This strategy is very simple to implement in which worst individuals are skipped and the chromosomes of best fitness values are carried forward for next iteration of Genetic Algorithm. Two points Partially Matched Crossover (PMX) operator has been implemented in order to produce new set of individuals for approaching generation. In this operator, two chromosomes are selected to perform the crossover randomly. In both selected chromosomes, two points (positions) are picked randomly over the chromosomes structure (genes) and these points are swapped mutually between the chromosomes. This operator may yield the illegal solution, therefore, IA agent performs the repairing to make the solution eligible. Table 2 present the values of different parameters utilized in the present work. These value are referred from Asadzadeh [17].

Table 2: Parameters and their values used for proposed approach

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Size</td>
<td>100</td>
</tr>
<tr>
<td>Number of Generations</td>
<td>100</td>
</tr>
<tr>
<td>Sub-Population Size</td>
<td>25</td>
</tr>
<tr>
<td>Migration Rate</td>
<td>5</td>
</tr>
<tr>
<td>Crossover Rate</td>
<td>0.95</td>
</tr>
<tr>
<td>Migration frequency</td>
<td>10 Number of Generations</td>
</tr>
</tbody>
</table>

7. CONCLUSION

In the present work, multi-agents are proposed to find the near optimal solution for job shop scheduling problem using Genetic Algorithm and Variable Neighborhood Search approach in parallel to improve the efficiency of search. The performance of the system is assessed by a small size case study of job shop scheduling problem and it reveals that the proposed approach is effective enough to find the optimal solution. In the future, Disturbance Agents (DA) has been planned to study the internal and external disruptions.

8. REFERENCES


