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Optimization of Job-Shop Scheduling Problem for Calculating Makspan using Modified TLBO Method

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Abstract
The paper presents the method for optimization of job shop scheduling problem, the mathematical model developed in the recent article has been used for optimization of makspan. TLBO (teaching–learning based optimization) is advanced method of optimization which is used for optimization with some modification. Here discrete generation has been created for the solution of job shop scheduling problem. The results are compared with benchmark problems and GT algorithm is also used for comparisons.

Keywords: *Job-Shop Scheduling, TLBO method, Makspan, GT algorithm*

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INTRODUCTION

Job shop scheduling is the prime requirement for any industry for better productivity and utility. These can be achieved using advanced methods in mathematical research and numerical technics.

Various optimization technics developed for solving numerical and analytical data are simulated annealing (SA), genetic algorithm (GA), tabu search (TS), ant colony optimization (ACO) particle swarm optimization (PSO) and artificial bee colony (ABC). These methods are also used for solving various industrial problems [1].

The functioning of TLBO (teaching–learning based optimization) is divided into two parts, namely 'Teacher phase' and 'Learner phase'. Functioning of both phases is explained below.

Teacher Phase

It is the first part of the algorithm where the learners learn through the teacher. During this phase, a teacher tries to increase the mean result of the class room from any value M1 to his or her level, (i.e., TA). But practically it is not possible and a teacher can move the mean of the class room M1 to any other value M2 which is better than M1 depending on his or her capability. Let Mj be the mean and Ti be the teacher at any iteration i. Now Ti will try to improve existing mean Mj towards it so the new mean will be Ti designated as Mnew and the difference between the existing mean and new mean is given by [2].

Difference_Meani=(Mnew–TFMj) (1)

Where TF is the teaching factor which decides the value of mean to be changed, and ri is the random number in the range [0, 1]. Value of TF can be either 1 or 2, which is a heuristic step, and it is decided randomly with equal probability as:
TF= round [1 + rand (0,1) {2-1}] (2)

Teaching factor is generated randomly during the algorithm in the range of 1–2, in which 1 corresponds to no increase in the knowledge level and 2 corresponds to complete transfer of knowledge. In-between values indicate the level of knowledge transfer. The transfer level of knowledge can be any level depending on learners' capabilities.

In this present study, an attempt has been made by considering values between 1 and 2, but no improvement in the results has been observed. Hence, in order to simplify the algorithm, it is suggested to take the teaching factor with the value 1 or 2 depending on rounding up criteria. However, any value of TF can be taken between

1 and 2. Based on this Difference Mean, the existing solution is updated according to the following expression,

Xnew,i= Xold;I + Difference_Meani (3)

Learner Phase

Learner phase is the second part of the TLBO algorithm where learners increase their knowledge by interaction among themselves. A learner interacts randomly with others for enhancing his/her knowledge. A learner learns new things if the other learner has more knowledge than him/her. Mathematically, the learning phenomenon of this phase is expressed below [3].

At any iteration i, consider two different learners Xi and Xj where $i \neq j$.

Xnew;i = Xold;i +ri (Xi -Xj) if F(Xi) <= F(Xj) (4)

Xnew;i = Xold;i +ri (Xj –Xi) if F(Xj) < F(Xi) (5)

Accept Xnew if it gives better function value. The implementation steps of the TLBO are summarized as follows:

Step 1: Initialize the population, (i.e., learners') and design variables of the optimization problem, (i.e., number of subjects offered to the learner) with random generation and evaluate them.

Step 2: Select the best learner of each subject as a teacher for that subject and calculate mean result of learners in each subject.

Step 3: Evaluate the difference between current mean result and best mean result according to Eq. (1) by utilizing the teaching factor (TF) (Eq. (2)).

Step 4: Update the learners' knowledge with the help of teacher's knowledge according to Eq. (3).

Step 5: Update the learners' knowledge by utilizing the knowledge of some other learner according to Eqs. (4) and (5).

Step 6: Repeat the procedure from step 2 to 5 until the termination criterion is met.

Literature Review

The Job Shop Scheduling Problem (JSSP) can be considered as the most common scheduling models standing in exercise which is surrounded by the toughest combinatorial optimization difficulties. Guo et al. suggested a common mathematical model of the JSSP for apparel assembly practice [4]. The aim of this model was to minimize the total penalties of earliness and tardiness by deciding when to start each orders production and how to assign the operations to machines (operators).

Genetic optimization process was implemented to resolve the model. Seda suggested a mathematical model for job shop scheduling problems established on mixed integer programming formulations [5]. Moghaddas and Houshmand recommended a mathematical model for job shop scheduling with sequence dependent setup times [6]. Mahavi et al. developed a model for a single machine bi-criterion scheduling problem with deteriorating jobs with the aim of decreasing total tardiness and work in process costs [7]. Shapiro has offered mathematical programming models and solution methods that have been useful to several types of production planning and scheduling problems [8].

Pan has delivered a review and assessment of mixed-integer linear programming (MILP) formulations for job-shop [9]. Blazewichz et al. is the first one that emphases on mathematical models for scheduling complications [10].

They presented mathematical programming formulations for single- machine, parallel-machine and job shop scheduling problems. Bowman and Dantzig not only still retain their original forms but have also been pushed into neglect [11,12]. This may be due to their low productivity and their disappointment to solve even small sized problems.

H. S. Kesari and R. V. Rao used TLBO [13]. TLBO is nature inspired population based optimization method. A solution in Job shop scheduling problem is an operation scheduling list which is represented as a student(x) in TLBO algorithm. Each student contains n*m dimensional corresponding to n*m operating operation based representation is used. The difference between two means is updated using PBX mechanism in teacher phase self-studying concept using VNS is used in student phase to reduce the complexes. Teacher phase helps VNS to find solutions as early as possible, exchanging and inserting process in VNS in used to find new solution in learner phase. TLBO is tested on 58 benchmark problems results are better than HGA, MPSO and MA, Standard deviation, Relative percent error (RPE) and mean of SD is used for comparison. TLBO can be extended for flow shop scheduling batch scheduling, FMS scheduling and AGV scheduling.

According to Baykasoglu et al. a random key based approach with the largest position valve rule is used for obtaining a job permutation for FSSP and JSSP [3]. TLBO is employed for FSSP and JSSP. GT algorithm is used for construction of active schedules within TLBO search. The objective considered is to minimize makspan.

They employed design of experiments (DOE) approach in order to find out the best possible parameter set in order to determine which control parameter effects are significant ANOVA is conducted. In order to have a comparison with the present TLBO results different methods like PSO, HIA, MA, and HPSO are used. The TLBO'S result is found comparable and acceptable.

Research Gap

Various researches have been done for the estimation of makspan based on dispatching rules and optimization technics. But as the numbers of operation and job increases will increase the length of problem, which also increase calculation time in drastic order. So the goal of these papers is to develop an optimization approach for the recently developed mathematical formula for job shop scheduling problem.

MATHEMATICAL MODELING FOR MAKSPAN

The mathematical formula for job shop scheduling has been developed in recent research work which can be used for optimization of makspan

Maximum Completion time,

$Z = \text{maximum } \{MTF_1, MTF_2, MTF_3 \ldots MTF_m\}$

Where, MTF_k is the machine final time for k-machine after completion of all the operation.

m is the number of machines.

MTF and MTI for each machine will be evaluated for each operation and final MTF will be considered for the objective.

$MTF = MTI + T_x$

T_x is the processing time of X (which identifies job E and operation F)

X_k is the job-operation sequence number or optimum sequence

$X_k = X_1 X_2 X_3 X_4 X_5 X_6 X_7 X_8 X_9 \ldots X_k$

1-1 1-2 1-3 2-1 2-2 2-3 3-1 3-2 3-3

Or 1 2 3 4 5 6 7 8 9

Or alternate sequence

1 1 1 2 2 2 3 3 3

Here, $X_1=1$ =>**1-1** is **job-1 operation-1**

$X_2=4$ =>**2-3** is **job-2 operation-3**

TLBO MODIFICATION FOR JOB SHOP PROBLEM

Teaching and learning based optimization technics is widely used in numerical data analysis. Mathematical model can be used for optimization of makspan. Objective function is used for making MATLAB code. Size of problem will crease if number of operation or jobs will increase.

Poisson distribution is used for creating population in TLBO, which creates so many unnecessary solutions. Generation control is required for handling complexity in problem so some new generation has been developed for job shop problem instead of passion distribution.

Discrete mathematics has been applied instead of Poisson distribution for creating population for reducing the length of problem. Discrete population generates those values which is feasible for current problem, so by avoiding unnecessary population, optimization time can be reduced.

Steps for Creating Discrete Population

1. Select integer numbers only
2. Select numbers from predefined set
3. Job selected based on availabilities
4. Operation sequenced followed during selection

OPTIMIZATION OF THE BENCHMARK PROBLEM USING

MODIFIED TLBO AND GT ALGORITHM

Benchmark problem of job shop scheduling (6-jobs and 6-machines) has been considered for the testing of algorithm.

Problem Description

6-jobs and 6-machine has been considered. Machine sequence and job operation time are given in the table given below:

Processing time (min)

	Processing time (min)					
Job/Order	**1**	**2**	**3**	**4**	**5**	**6**
1	01	03	06	07	03	06
2	08	05	10	10	10	04
3	05	04	08	09	01	07
4	05	05	05	03	08	09
5	09	03	05	04	03	01
6	03	03	09	10	04	01

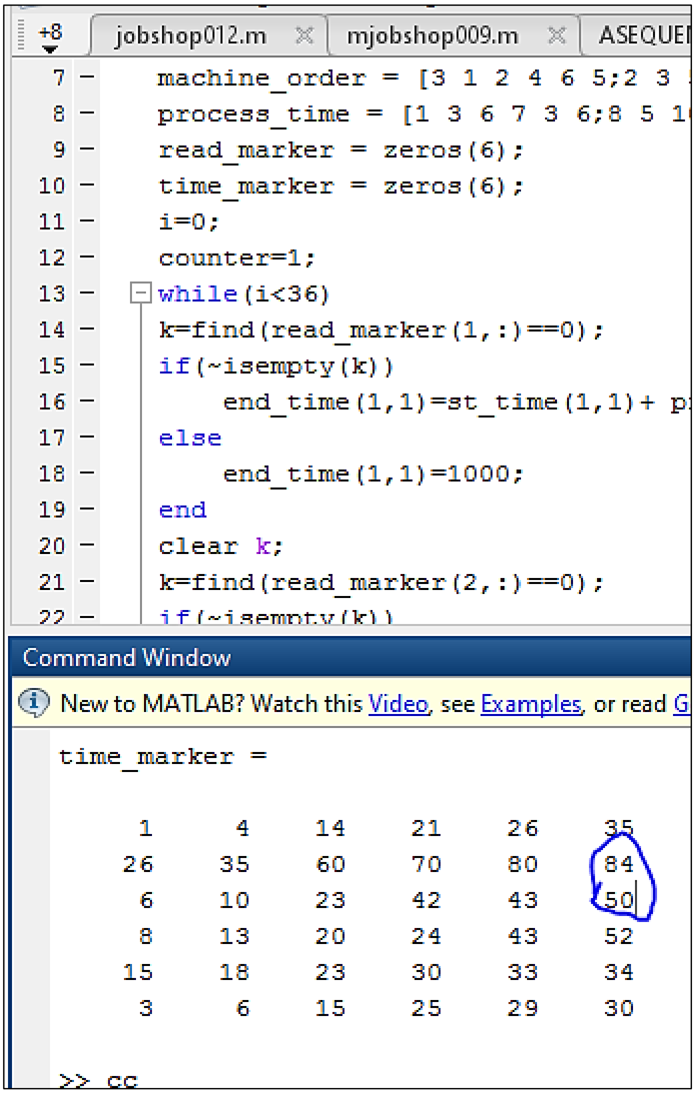
Machine order

	Machine order					
Job/Order	**1**	**2**	**3**	**4**	**5**	**6**
1	M 3	M 1	M 2	M 4	M 6	M 5
2	M 2	M 3	M 5	M 6	M 1	M 4
3	M 3	M 4	M 6	M 1	M 2	M 5
4	M 2	M 1	M 3	M 4	M 5	M 6
5	M 3	M 2	M 5	M 6	M 1	M 4
6	M 2	M 4	M 6	M 1	M 5	M 3

Solution using GT Algorithm

GT algorithm has been prepared, which is dispatching rule for solving job shop scheduling problem.

The solutions obtained for the bench mark problem are as follows:



Optimum Makspan = 84 min
Best Solution = 1 6 1 3 6 4 3 4 1 5 6 5 4 1 3 5 4 6 1 2 6 5 6 5 5 1 2 3 3 4 3 4 2 2 2 2

Solution using TLBO Algorithm

TLBO optimization approach has been used along with discrete population; the results obtained under different populations are as follows:

No.	Population size	Best cost
1	10	84
2	100	70
3	1000	61
4	5000	61
5	10000	61

Optimum Makspan = 61 min
Best Solution: [1 13 19 20 2 25 7 14 31 8 32 21 15 16 3 17 22 33 26 9 4 10 5 23 18 27 34 24 6 11 35 36 12 28 29 30]

CONCLUSIONS

Optimization using modified TLBO performed for benchmark problem. The results obtained are under the optimum range. It provides better results as compared to dispatching rules. So currently developed optimization approach for job shop scheduling can be used for various industrial problems.

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