International Journal of Mechanical and Production Engineering Research and Development (IJMPERD)
ISSN(P): 2249-6890; ISSN(E): 2249-8001
Vol. 8, Issue 6, Dec 2018, 465-478

A GRAVITATIONAL SEARCH BASED ON THE OPTIMIZATION OF JOB SHOP SCHEDULING PROBLEM

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ABSTRACT

In a multi-factory optimization preparation, job allocation to a suitable factory or adjustable developed component is a basic task. It encompasses the consideration of hardware implementation, technology, capability, and an exploitation stage for each construction line or gathering component. The reduction of invention expenditure and manufacturing capabilities are used to develop the competitiveness, an effectual construction system and also diminishes the obtainable working time. The foremost target of this work is to diminish the overall order conclusion time (i.e., makespan) by the aid of innovative Gravitational Search Algorithm related optimization procedure. The anticipated method is executed on the functioning platform of MATLAB. The consequences were examined and distinguished by further obtainable methods.

KEYWORDS: Gravitational Search Algorithm (GSA); Genetic Algorithm (GA); Artificial Bee Colony (ABC); Job Shop Scheduling Problem (JSSP); Job Shop Scheduling Problem (JSSP); Flexible Job-shop Scheduling Problem (FJSP)

Received: Aug 18, 2018; **Accepted:** Sep 12, 2018; **Published:** Nov 12, 2018; **Paper Id.:** IJMPERDDEC201850

Original Article

1. INTRODUCTION

Generally, the liability and component alterations are contained by the real-world structure for to demand job shop settings. According to the deviation in the shops, scheduling is difficult because scheduling decisions are desiring to be prepared hurriedly [1]. The job-shop scheduling problem (JSP) is generally focused in the recent tracks and it illustrates by the deliberation of scientists and specialists. The conventional JSP is generally distinguished by no jobs. Here, each job contains a particular collection of functions. These functions are arranged by means of the machines or work stations in a specified day and age which is pointed out by a specified particular precedence position. A calendar is prepared to bind a computation (or numerous measures) of implementation [2]. Each job must undergo each machine at once. Each job is maintained during the machines in a precise demand and there is no precedence necessities in the middle of diverse job function [3]. Each machine is must maintain a solitary job promptly and it can't be interrupted. Moreover, the conducting time is established and identified. The problem is to determine a schedule to bind the traverse.

Systematic solution approach is used to diminish the augmentation of difficulty size and the logically anticipated shops are not expensive in a dynamic legitimate situation, in which, the modification of processes and machines are modify the schedule [4]. In this manner, Operation Research (OR) is used to alternate the transmitting principles or heuristics for to resolve the convenient occurrence in reasonable time. Additionally, the problems of scheduling can be categorized as deterministic and nondeterministic classes which are derived from

the quantity of vulnerability associated through the input limitations. The deterministic scheduling representation is not including vulnerabilities rather than the actuality problems such as machine stoppage, diversity in due dates and requirements, and irregular organizing times, which are disturbing the operational events [5]. Branch-and-bound (BB) or Dynamic Programming (DP) is a prospective policy for discovery the accurate perfect preparations by means of supplying diverse contender preparations in definite unreasonable condition. Though, these events are not capable and convincing in managing the enormous size of problems. Suppose, if the amount of state features, is increased, then the DP faces the space explosion problems [6].

Furthermore, the suitable transmitting regulations are selected by a heuristic and computerized analysis processes which derives from shop situation. Suppose, if the regulation resolving methods are relying on contender regulations, then it gives a hopeful conclusion which may not be available for a precise accumulating surroundings or a precise implementation computation [7]. Some of the meta-heuristic procedures are GA, reproduced strengthening (SA), and Cuckoo Search. In this process, an assembling structure was examining the problem of time-tabling. The analysed goal is integrated the reduction of machine affecting time, stream time, and additionally construct negotiation. In this manner, the problem of job-shop booking on solitary machines was inspected. Suppose, if these principles are available, then they are not actually the finest ones [8]. An effectual island representation of GA (NIMGA) is exploited for JSSP and it exploits an environment stimulated progression display and an additional truly provoked association resolve element, in which, each island exploits an interchange conversion proprietor along with the self-adjustment phase of growth, and most remarkably appalling populace through the least wellness progress initial to the adjacent islands observance in mind the target to situate a better occasion to subsist in a more sensible island. NIMGA is a realistic representation of the environment than the conventional IMGA, because it replicates the normal development in an enhanced manner [9, 10].

2. LITERATURE SURVEY

Hegen Xiong *et al*[11] have clarified a simulation-related examination of transmitting regulations for preparation in an active job shop through batch discharge enchanting into a description of the comprehensive scientific superiority limitation. This expression can be distinct as the expansion of predictable routing-related scientific superiority limitation. Relating to tardiness values, the comparative presentations of few broadly employed transmitting regulations were exploited. The efficiency of the four transmits regulations is exposing that the comparative presentation of transmitting regulations could be influenced by means of several representation limitation. For the typical job shop preparation, the difficulty representations have no comprehensive scientific preference, limitation among jobs, in addition to the representation obtaining into describing the comprehensive scientific preference restriction. It was exposed to diminishing the overall delay and the proportion of delayed jobs. The four transmitting regulations were very effectual. Concerning delay-related intention, the comparative presentation of the examined transmitting regulations could be influenced by means of altering the stage of the comprehensive scientific superiority limitation, but as well the due date stiffness.

Kameng Nip *et al*[12] have explained that the combinatorial advancement inconveniences were joining the great open shop or occupation shop arrangement trouble and the most brief way trouble. It picks a division of employments that contain a feasible clarification of the most limited way trouble. A while later, execute the favoured employments on the shop machines to reduce the build traverse, i.e., the former accomplishment time of the whole occupations. They built up that these inconveniences were NP-hard in two machines. Assume, if the amount of machines was an info, at that point they represent that it was far-fetched to find harsh count calculations through introduction extent improved than 2 aside

from P = NP. They utilize an unconstrained figure calculation in the amount of machines as an info, and enhance guess calculation in the amount of machines as foreordained. Moreover, they utilize a polynomial time guess organize for the open shop condition in the amount of machine was foreordained.

Rui Zhang *et al*[13] have depicted an increasing apprehension in the ecological collision of conventional manufacturing, particularly in expressions of energy utilization and the interrelated discharge of carbon dioxide. Moreover the implementation of utensils, construction preparation could perform a significant function in dropping the overall energy utilization of a developed plant. They clearly initiate the intention of diminishing energy utilization into a distinctive construction preparation representation, i.e., the job shop scheduling difficulty is derived from the machine speed scaling structure. To resolve that bi-intention optimization difficulty, they employ a multi-objective genetic algorithm integrated through two difficulties-precise limited enhancement policies. These limited enhancement actions intend to augment the explanation superiority through exploiting the arithmetical representation of two limited sub troubles founded on the innovative difficulty.

Hao Gao *et al*[14] have anticipated a procedure for the activity shop booking issue (JSSP) which got from the combination meta heuristic process. This procedure is utilized for the characteristics of an improved molecule swarm streamlining (PSO) and a Tabu pursuit (TS) calculation. It was utilized to inspect an essential segment methodically. The rest of the approach was started in the PSO for building up its examination capacity. Subsequently, the improved PSO could supply different and best preparatory clarification to the TS for creation a prevalent explores in the overall space. They likewise use a constrained look approach for gaining improved outcome in JSSP. A genuine whole number encodes and interpret, organize for relating a clarification in consistent space to a segregated arrangement clarification was planned for the upgraded PSO and the Tabu calculation to transparently relate their clarification for becoming the research of improved clarification.

S. Meeran *et al*[15] have clarified a Job Shop Scheduling trouble by methods for a various assortment of utensils and systems, for example, Branch and Bound at one final piece of the field and Heuristics at the supplementary end. However, the exposition evaluations are suggested that these techniques were satisfactory on their person to determine that adamant NP-hard trouble. In this manner, it was propose that a legitimate clarification process needed to build up the noteworthy characteristic of various arrangements. Right now they gave one such clarification procedure to coordinating Genetic Algorithm and Tabu Search. The establishment of such combination process as in the state of further a framework which utilize GA and TS was to join the extension all inclusive inquiry and develop constrained hunt fitness of GA and TS correspondingly. The fusion representation employed as exceed in many comparable systems of conventional standard troubles and real-life troubles. In this process, the system accomplish the mutual collision of numerous diminutive but significant attribute such as dominant chromosome depiction, effectual genetic operatives, limited neighborhood policies and competent search policies together with original preliminary explanation. The system's sensible convention features are exhibit that the system was regularly competent of resolving the actual life Job Shop troubles.

Yoni. Nazarathy *et al*[16] have declared an extraordinary amount of employment shop booking inconveniences, in which a foreordained amount of machines, a delimited amount of activities per work, and an awesome amount of occupations were actualized. In the gigantic amount of occupation shops, it builds to determine a liquid trouble and to program the employments in such a way as to take after the liquid clarification. There had been various records which utilized assessed clarifications were asymptotically most positive as the amount increases. It was unspecified that the

difficulty contains several indistinguishable copies of a predetermined group of jobs. They employ a very undemanding heuristic which could program such troubles. They converse asymptotic optimality of this heuristic, beneath a broad collection of formerly uncultivated circumstances.

3. PROPOSED GSA BASED JSSP METHOD

The Flexible Job shop Scheduling Problem (FJSP) is appropriate for the conventional job scheduling difficulty which is overcome by whichever machine contains pre-arranged preparation. The correctly systematized functions of the machines are helping to diminish the necessity of working time in the JSSP procedure, in order to accomplish the consumer requirements The fundamental capability is to distribute each solitary task to a machine and to compile the capability on the machines, every single one together that the maximum expression of consummation (make span) of the entire task is reduced to the bottom. Each procedure is to be switched by means of diverse machines, in a specified demand. The problem is to determine a program of the irrelevant time to terminate the entire jobs. Therefore, the distinguishing standard troubles are measured to diminish the construct duration time of the complete mission by means of Gravitational search Algorithm (GSA) related optimization procedure. The anticipated Optimization progression reflects on the intention task (i.e., fitness function) because to reduce the make span time. Suppose, if the preferred make span time or greatest iteration is accomplished, then the system is premeditated to conclude.

3.1 System Model Formulations and Assumptions

Here, if the activity obtains diverse jobs, then it requests to allocate the jobs to a logical factor in the intervening time. The scheme of job preparation must terminate the complete task, at least span time. The fundamental intention of this process is to augment the implementation efficiency. Jobs are premeditated by several optimization principles and the produced procedures are evaluated for various implementation conditions like the smallest amount of expenditure, slightest make span time, slightest tardiness, severe resource exploitation, and so on.

In this paper, the $(j \times m)$ is indicating the least make span common job shop scheduling difficulty, that can be signified by means of a group of ' j ' jobs, S_J . The managing of j^{th} job (S_J^j) on the m^{th} machine ($S_{F,M}^m$) is recognized as the function, $S_{J,O}^o$. Function $S_{J,O}^o$ necessitates the discriminating exploitation of machine $S_{F,M}^m$ for a constant period $t_{j,o,m}$ (i.e. processing time). A plan is a group of overriding times for each function that gratify the intention task. The purpose of the anticipated optimization difficulty (i.e. objective function) is to bound the make span time. The make span time T is the mandatory time to terminate every single one of the jobs. The preparation difficulty is compound, because it requires adjusting the particular complexity of $(j \times m)$ least makespan common job shop preparation difficulty. The common job shop difficulty contains ' j ' jobs and ' m ' machines, therefore the quantity of reasonable explanation is $(j!)^m$.

3.1.1 Formulations (Input Parameters)

Let the set of factories, machines, jobs and its operations be represented by the following equations (1), (2), (3), (4) respectively.

$$S_F = \{S_F^1, S_F^2, \ldots, S_F^f\} \quad (1)$$

$$S_{F,M} = \left\{S^{1}_{F,M}, S^{2}_{F,M}, \ldots, S^{m}_{F,M}\right\} \quad (2)$$

$$S_{J} = \left\{S^{1}_{J}, S^{2}_{J}, \ldots, S^{j}_{J}\right\} \quad (3)$$

$$S_{J,O} = \left\{S^{1}_{J,O}, S^{2}_{J,O}, \ldots, S^{o}_{J,O}\right\} \quad (4)$$

Where,

S_F - set of factories and S^{f}_{F} denotes the f^{th} factory

S_J - set of jobs and S^{j}_{J} denotes the j^{th} job

$S_{J,O}$ - number of operations in j^{th} job 'S^{j}_{J}' and $S^{o}_{J,O}$ denotes the o^{th} operation

$S_{F,M}$ - set of machines and $S^{m}_{F,M}$ denotes the m^{th} machine

Moreover, some other parameters related to time that are essential in computing the objective function are given as follows,

$T_{j,f}$ -Deadline time for delivering a job 'j' from factory 'f' to the hub

$T^{D}_{j,o,f,m}$- Total time duration required for any operation 'o' of a job 'j' in a machine 'm' from the set of factories S_F

$T^{S}_{j,o,f,m}$ - starting time of an operation 'o' of a job 'j' in a machine 'm' from the set of factories S_F

$T^{B}_{j,o,m}$ - Beginning time of any operation 'o' of a job 'j' in the machine 'm'

$T^{E}_{j,o,m}$ - Ending time of any operation 'o' of a job 'j' in the machine 'm'

The step by step procedure taking place in the GSA procedure is given as,

3.1.2 Assumptions

The job S^{j}_{J} encompasses S_O group of functions, which must be maintained by means of a predefined progression.

- At some point in the function of a machine, apart from of collapse, injure, or substance insufficiency, once each function is in line, neither discontinue movement nor reprocessing is acceptable.
- The implementation of function $S_{J,O} \in S_O$, $S_O = \left\{S^{1}_{O}, S^{2}_{O}, \ldots, S^{o}_{O}\right\}$ of job, $S_J \mid S_J = \left\{S^{1}_{J}, S^{2}_{J}, \ldots, S^{j}_{J}\right\}$ preferred from a group of obtainable machines, $S_{F,M}$.
- Each one machine can carry out a solitary function $S_{j,o}$ at some specified time and the transportation times among machines are ignored.
- Each function of a job must be prearranged to one solitary factory to allocate the job.

3.1.3 Objective Function (Fitness Function)

The objective function is the minimum of makespan time, T, that can be formulated as,

$$Fitness = Min(T) = Min\left\{ Max\sum\sum\left(T^{S}_{j,o,f,m} + T^{D}_{j,o,f,m}\right) + T_{j,f} \right\}$$

For reaching the objective function, the proposed JSSP introduces Gravitational Search Algorithm based optimization procedure.

3.2 Gravitational Search Optimization Algorithm

The Gravitational Search Algorithm (GSA) is derived from the activities of Newton's gravitational force which was anticipated by means of Rashedi. In this algorithm, mediators are indicated as models and their presentation is considered by means of their loads. Each model is magnetizing supplementary by the help of gravitational force, and this force origin a comprehensive progress of the entire model in the direction of the model through heavier masses. Hereafter, loads exploiting a straight structure of communication by the aid of gravitational force. At GSA, each one mass (agent) encompasses four terms such as the location, the inertial mass, active gravitational mass and the passive gravitational mass. For each explanation, the gravitational and inertial masses are premeditated by means of fitness task. Based on the loads, force and accelerations are calculated. At last, the velocity and location of the mediators are modernized by the stepping up elements. The entire limitations are modernized in termination.

Here, the flow diagram of the GSA optimization procedure is depicted in the following figure 1.

Step 1: Initialization

Based on the quantity of functions and the reasonable machines, input populace 'M' is erratically established by means of unsystematic location athe mediatorois signified j^{th} mediator is signify by the subsequent association:

$$Y_j = \left(y^1_j, y^2_j, \ldots, y^n_j, \ldots, y^m_j \right) for = \left(j = 1,2,\ldots,M \right) \quad (5)$$

Where, y^n_j is the position of j^{th} agent value in the n dimension

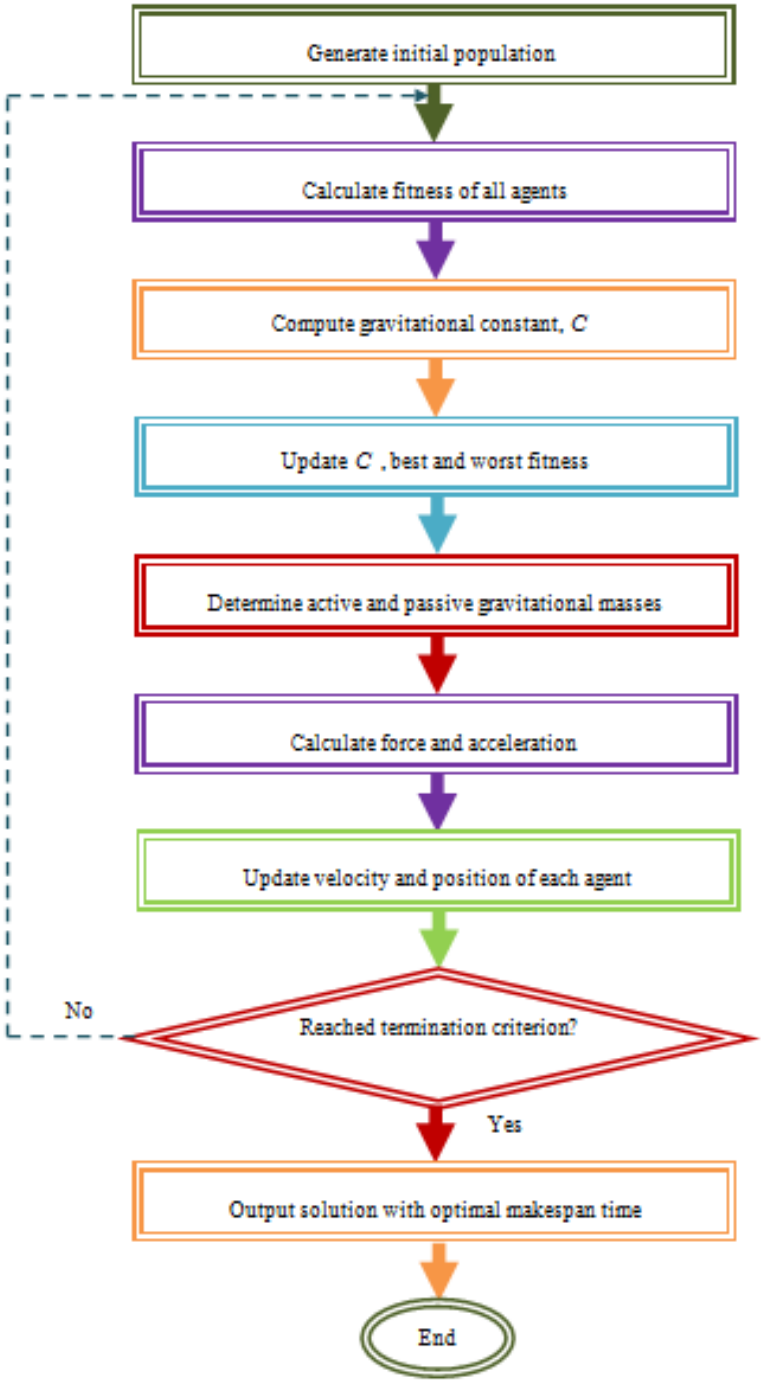

Figure 1: Flow Diagram for GSA

Step 2: Fitness Calculation

In this step, the fitness evaluation is done by utilizing the objective function.

$$Fitness_{p}(k) = Min(T) \tag{6}$$

Where, $Fitness(k)$ indicates the fitness of p^{th} mediator at k^{th} iteration. The fitness value is declared as $Fitness(k)$, the finest and nastiest fitness for the entire mediator are estimated at quantity of iteration. The finest and

nastiest fitness are declared as:

$$Fitness_{best}(k) = \max_{p\in(1,..,M)} Fitness_p(k) \tag{7}$$

$$Fitness_{worst}(k) = \min_{p\in(1,..,M)} Fitness_p(k) \tag{8}$$

Step 3: Gravitational Constant (C) Computation

The gravitational constant C is located at the establishment which is measured by a phase of time to accomplish the search accuracy. The gravitational constant is specified as,

$$C(k) = C_0 e^{\left(-\lambda\frac{k}{K}\right)} \tag{9}$$

Where, K is the maximum iteration and λ and C_0 are constants

Step 4: Update C , Best and Worst Fitness

For the period of iteration, the finest and nastiest fitness values were modernized occasionally in the Gravitation constant which is derived from the preceding explanation.

Step 5: Gravitational and Inertial Masses Computation

According to the fitness values, the Gravitational and inertia masses were premeditated. A heavier load illustrates an enormously competent explanation. Presuming the correspondence of the gravitational and inertia mass, the values of load is evaluated by means of the plan of fitness.

$G_{aj} = G_{pj} = G_{ij} = G_j$, where $(j = 1,2,\ldots,M)$

The mass of j^{th} agent is calculated as,

$$G_j(k) = \frac{g_j(k)}{\sum_{p=1}^{M} g_p(k)}$$

In the above equation, $g_j(k)$ can be obtained as,

$$g_j(k) = \frac{Fitness_j(t) - worst(t)}{best(t) - worst(t)} \tag{10}$$

Where, G_{aj} , G_{pj} , G_{ij} and G_j are the active gravitational mass, passive gravitational mass, inertial gravitational mass and the massof j^{th} agent. Also, $Fitness_j(t)$ signifies the fitness value of j^{th} agent at k^{th} iteration.

Step 6: Total Force and Accelerations Calculation

Then the force and acceleration values of the j^{th} agent is determined, that can be expressed as:

$$Force_j^n(k) = \sum_{p \in qbest, p \neq j} rand_p \; Force_{jp}^n(k)$$

$$Acc_j^n(k) = \frac{Force_j^n(k)}{G_{ij}(k)} \tag{11}$$

Where, $Force_{jp}^n(k)$ is the force acting on the j^{th} agent by p^{th} agent.

Step 7: Update Velocity and Position

Moreover, the established velocity is anticipated by means of the regulation of movement. The velocity calculation is denoted by the ensuing equation:

$$V_j^n(k+1) = rand_j \times V_j^n(k) + Acc_j^n(k) \tag{12}$$

Where, $rand_i$ denotes the uniform random variable in the interval [0, 1]

At present, the location of the mediator will be restructured by means of the anticipated velocity and the location renewing is organized by means of the ensuing equation:

$$Position_j^n(k+1) = Position_j^n(k) + V_j^n(k+1) \tag{13}$$

Step 8: Repeat

Reiterate the procedure up to the best solution is attained.

Step 9: Terminate

Subsequent to accomplishing the finest explanation through negligible makespan time, the quantity of iteration is concluded.

4. RESULTS AND DISCUSSIONS

This segment explains about the result and discussion of an effectual Job Shop Scheduling difficulty by means of GSA related optimization procedure. The anticipated, algorithm is accomplished by the aid of MATLAB software and the testing is taking place by a system of encompassing 4 GB RAM and 2.10 GHz Intel I-3 processor.

The effectiveness of the anticipated GSA related optimization algorithm on JSSP is investigated by means of 20 standard troubles of unreliable size. This obtained data is exploited in estimating the Makespan time of diverse optimization related JSSP. The investigational consequences of diverse optimization related JSSP were examined in this segment. Additionally, evaluation is prepared for the typical Makespan time and the replicated consequences.

Table 1 gives the original and simulated Makespan Time values (in seconds) for a number of Benchmark problems.

Table 1: Make Span Time for a Number of Benchmark Problems

Benchmark Problems	Size $(j \times m)$	Make Span Time (Seconds)			
		Original	GSA	ABC	GA
FT10	6×12	930	887	909	928
LA01	10×20	666	635	641	642
LA02	10×10	655	602	641	643
LA03	10×10	597	563	573	592
LA04	10×10	590	558	569	571
LA05	10×10	593	560	582	585
LA06	15×10	926	843	869	881
LA07	15×10	890	844	877	882
LA08	15×10	863	812	842	862
LA09	15×10	951	916	918	951
LA10	15×10	958	910	931	950
LA11	20×10	1222	1163	1167	1200
LA12	20×10	1039	981	998	1028
LA13	20×10	1150	1106	1110	1146
LA14	20×10	1292	1207	1220	1245
LA15	20×10	1207	1148	1168	1200
LA30	20×20	1355	1341	1343	1355
LA31	30×20	1784	1758	1769	1777
LA33	30×20	1719	1691	1719	1719
LA35	30×20	1888	1866	1866	1868

From the above table,

- It is distinguished that the least Makespan time (i.e. 558sec) is accomplishing for the standard difficulty 'LA04' of size (10×10) for the anticipated GSA optimization related JSSP. Additionally, it is better than 568 se for the entire supplementary process.
- Moreover, it can be observed that the Makespan time is condensed for the anticipated method even if the size of the standard difficulty is elevated.
- Since the acquired consequences, the replicated consequences in the course of optimization related JSSP are enhanced than the innovative Makespan time values.
- Additionally, the evaluation of optimization related JSSP methods, the GSA related JSSP provides the smallest amount of Makespan time.
- The ABC related JSSP as well offers considerable consequences, but the replicated consequences for definite standard troubles were not indicating the spot. Therefore the anticipated GSA related JSSP locate frontward than the entire further methods.

Additionally, the evaluation scheme for the unique in addition to the replicated Makespan time values are calculated with the help of anticipated GSA optimization related JSSP and further optimization related JSSP such as ABC, GA is specified in the beneath figures 2 to 5.

The figure 2 is used to illustrate the innovative in addition to the replicated Makespan time values for the standard troubles like FT10, LA01, LA02, LA03 and LA04.

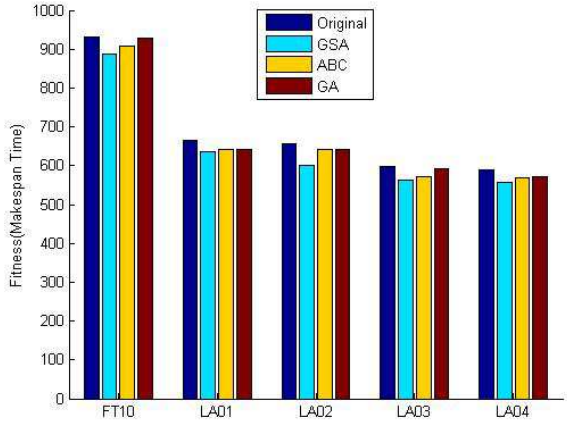

Figure 2: Make span time for 5 benchmark problems (FT10, LA01, LA02, LA03, LA04)

For the standard troubles like LA05, LA06, LA07, LA08 and LA09, the innovative and the replicated Makespan time values were conspired in figure 3.

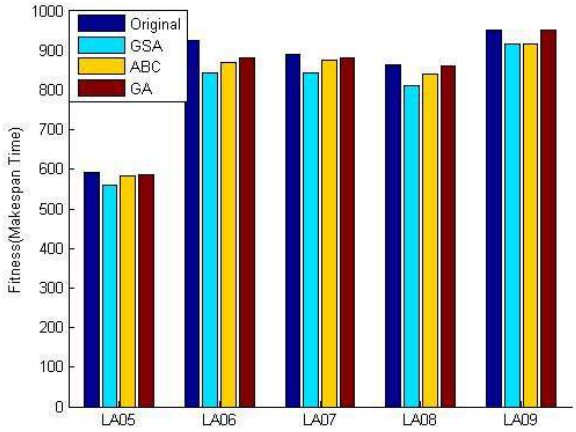

Figure 3: Make Span Time for 5 Benchmark Problems (LA05, LA06, LA07, LA08, LA09)

The figure 4 and 5 explains about the innovative and the replicated Makespan time values for the group of standard troubles (LA10, LA11, LA12, LA13, LA14) and (LA15, LA30, LA31, LA33, LA35) correspondingly.

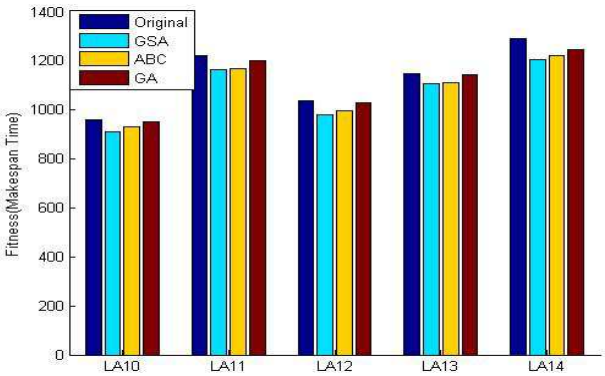

Figure 4: Make Span Time for 5 Benchmark Problems (LA10, LA11, LA12, LA13, LA14)

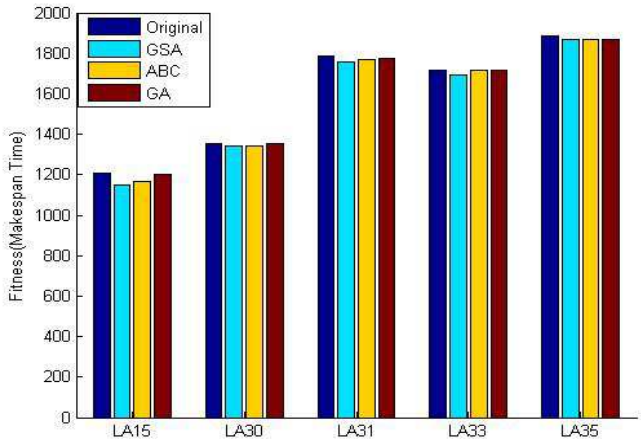

Figure 5: Make Span Time for 5 Benchmark Problems (LA15, LA30, LA31, LA33, LA35)

5. CONCLUSIONS

This document is used to resolve the job shop scheduling difficulty with the help of GSA related optimization procedure. At this point, the accomplishment is prepared with the help of twenty rough standard occurrences and the replication consequences were effectively achieved and examined for further obtainable optimization related JSSP methods predominantly, ABC and GA related optimization process. The entire investigation consequences are illustrated that the anticipated GSA optimization related JSSP surpass supplementary process for the entire standard troubles.

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