JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

"Optimization of Job Shop Scheduling Performance Measures using Hybrid Approaches"

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ABSTRACT

The job shop scheduling problem is extremely difficult to solve since it is a strong NP-hard issue. The two most common techniques for addressing JSP are direct and heuristic methods. This study has sought and developed effective hybrid heuristics for dealing with issues of massive scale and producing high-quality answers. The multi-objective optimization takes into account more than one goal. The first goal is to find a set of solutions that are as close as possible to the Pareto-optimal front. The second goal is to come up with as many different solutions as possible. Many problems in the real world have more than one goal, which makes them more interesting to solve. This research has tried to find a solution to this problem of multi-objective optimization. Multi- objective benchmark tasks are used to design and test algorithms for the Hybrid Sheep Flocks Heredity Model and the Artificial Immune System Shifting Bottleneck Algorithm. When compared to the Artificial Immune System Shifting Bottleneck Algorithm and other findings from the literature, the Hybrid Sheep Flocks Heredity Model Algorithm is shown to be an effective tool for tackling multi objective problems issue.

KEYWORDS: SFHM, MULTI-OBJECTIVE OPTIMIZATION, JSP, GA

1. CONCEPT OF JSP

Job shop scheduling, also called the "job-shop problem," is an optimization problem in which the best jobs are given to the right resources at the right times. The job shop scheduling problem is made up of a set of m machines (M1, M2,M3,..., Mn) & n jobs (J1, J2,J3,..., Jn) that need to be scheduled so that each job only goes through each machine once (Baker,1974). Each job has its own order of processing, which may have nothing to do with the order of processing of any other job. Often, technological limitations mean that each job must be done on the machines in a certain order or according to what comes first.

2. MEANING OF MULTI-OBJECTIVE OPTIMIZATION

Multi-objective optimization usually has more than one optimal solution, called a Pareto optimal solution. In the Pareto optimal solution, it is hard to say that one solution is better than the other. Heuristic methods can be used in multi-objective optimization to find Pareto-optimal solutions.

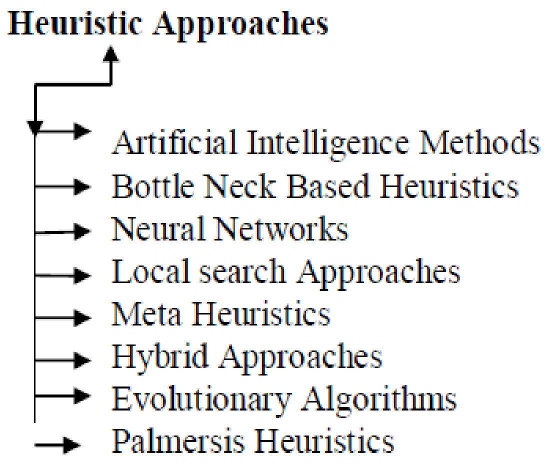

FIG 1. HEURISTICS APPROACHES FOR JOB SHOP SCHEDULING

3. REVIEW OF PAST STUDIES

The previous two decades have seen a lot of study on scheduling. By taking into account diverse goals, numerous ways have been created and put into practice for tackling various scheduling issues in job shops. The methods used to solve the scheduling issue in job shops served as the basis for the literature study.

RAJA AWAIS LIAQAIT et al. [1], paper is to give a full look at both centralized & decentralized JSSP methods in the Industry 4.0 environment. It described about centralized JSSP models as well as problem-solving methods, including their pros and cons. The second part of this paper explained an overview of the techniques used in the Industry 4.0 environment. In the third part of this paper, the latest research trends in this field are used to talk about the change from traditional job shop scheduling to decentralize JSSP. Lastly, this paper shows how JSSP research and use can look to the future, taking into account how strong JSSP is & current pandemic situation.

AHMADIAN et al.[2], Just-in-time job-shop scheduling (JIT-JSS) is a type of the job-shop scheduling problem in which each operation has its own due date and a penalty is charged if the operation is finished early or late. To solve JIT-JSS, we make a variable neighborhood search (VNS) algorithm. The algorithm works by breaking JIT-JSS into sub problems, finding the best or almost best way to do the operations for each of the smaller problems, and making a schedule for JIT-JSS by figuring out when the operations will be done.

REDDY MS et al. [3], heuristic techniques were also used for other designing application problems due to their power and conjunction with global optimums. The heuristic approach to learning entails revelation & critical thinking via the use of reasoning and prior experience. A technique lacking explicit execution certainty might be labeled "heuristic." These heuristic methods are used pragmatically when no superior methods are available. Artificial Intelligence, Bottleneck-based heuristics, Local search approaches, Meta Heuristics, and Hybrid Approaches are some of the heuristic techniques addressed in the next section.

WANG B et al. [4], Annealing (SA) is a combinatorial advancement technique based on random evaluations of the goal task, allowing for advancements out of a local minimum. SA is dependent on the resemblance to the real cycle of metal cooling & recrystallization. Generally, honey bee settlement optimization is used to assess performance indicators associated with work shop planning, such as machine utilisation, process time, throughput rate, and stock levels. Utilization of assembling assets is the most essential of these actions for any assembling project.

DENG Q et al. [5], the molecular swarm concept was dependent on the social behaviour of feathered creatures. The first objective was to artistically recreate the graceful but quirky motion of a bird in flight. A PSO calculation mimics the behaviour of avian feathery animals and their ways for data exchange in order to address enhancement difficulties. PSO has been introduced as a solution for simplifying actual number spaces. In addition to being problem-free, the PSO computation requires minimum explicit information applicable to a specific problem. This renders PSO more powerful than multiple other research methods.

4. OBJECTIVES OF MY RESEARCH WORK

The study conducted involves the following aims:

1. The creation of effective hybrid heuristics techniques.

2. Implementation of hybrid techniques for scheduling issues with multi objectives in job shops.

3. Formulation of multi-objective functions with weights and solution of multi-objective JSP problems using hybrid heuristic techniques.

5. ASSUMPTIONS MADE FOR SOLVING JSP

The following assumptions are made while solving job shop problem:

a. Each task necessitates m machines to perform the necessary procedure.
b. Machines never malfunction and thus are accessible during the whole schedule time.
c. Pre emptions are not permitted.
d. No parallel processing occurs.
e. The processing sequence is not same.
f. Operations cannot be suspended

6. CONSTRAINTS

In general, job shop scheduling uses the following constraints:

A). A task is not executed more than once on the same computer.

B). each machine can only do a single task at a time.

C). the job's due date.

7. MULTI OBJECTIVE JOB SHOP MODEL

A problem with much more than one objective function is called a "multi objective optimization problem." Most real-world decision-making problems involve more than one goal. This model takes into account three goals, such as the makespan, mean flow time, but also mean tardiness. The mean flow-time is the estimate of all jobs' flow-times. The average amount of tardiness at all jobs is called "mean tardiness." Equation 1 shows how to make a combined objective function with weights to minimize all the goals at the same time.

The overall goal function for the Job Shop Problem with multiple goals is:

$$COF = Min\ [w_1\ (msi/ms^*) + w_2\ (Ti/T^*) + w_3\ (mfi/mf^*)] \qquad (1)$$

Where, $w_1 + w_2 + w_3 = 1$.

COF = COMBINED OBJECTIVE FUNCTION

w_1, w_2, w_3 = WEIGHTAGE FACTORS

ms^* = MAKESPAN GLOBAL MINIMUM

Ti = MEAN TARDINESS ITERATION MINIMUM

T^* = MEAN TARDINESS GLOBAL MINIMUM

mf^* = MEAN FLOW TIME GLOBAL MINIMUM

ms_i = MAKESPAN ITERATION MINIMUM

mfi = MEAN FLOW TIME ITERATION MINIMUM

The Pareto optimum set, a family of the best trade-off schedules, may be identified in this situation. The Pareto front is the collection of Pareto solutions. A Pareto optimization challenge is therefore one that involves addressing a multi-objective scheduling issue. Fig.5.1 depicts the Pareto optimality strategy using weights. f_1 & f_2 are objective functions, and traced solutions A, B, E & G are workable.Fig.5.1 depicts the Pareto optimality strategy using weights. f_1 & f_2 are objective functions, and traced solutions A, B, E & G are workable.

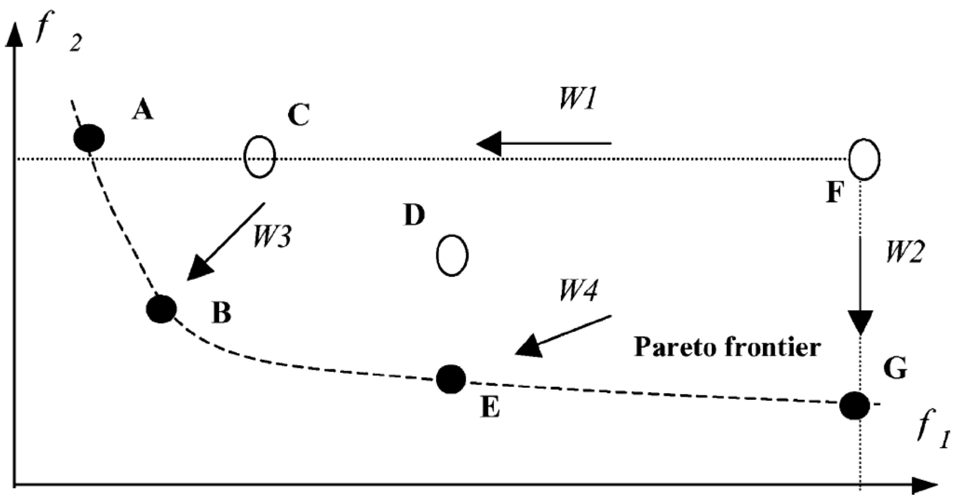

FIG. 2 PARETO OPTIMALITY METHOD

An optimization problem with numerous objective functions is referred to as a multi-objective optimization problem. A multi-objective optimization issue may be expressed mathematically as:

$$\min(f_1(x), f_2(x), \ldots\ldots, f_k(x))$$

$$\text{s.t. } x \in X,$$

The two job shop scheduling benchmark problems (Garen, 2004) with due dates are used in this research work:

I .the very first problem is an instance with ten jobs & five machines (JSP 1).

II. Ten jobs on ten machines is the second problem (JSP 2).

8. **SOLUTION METHODS**

The following hybrid heuristic approaches have been used to solve the multi objective job shop scheduling benchmark problems:

1. **Hybrid SFHM Algorithm:** Hybrid Sheep Flocks Heredity Model Algorithm.
2. **Hybrid AISSB Algorithm**: Hybrid Artificial Immune System Shifting Bottleneck Algorithm.

1. HYBRID SFHM ALGORITHM:

The suggested hybrid algorithm processes the original sequence with the AIS method and afterwards refines the results using the SFHM algorithm. The operational mechanisms of the immune system are computationally highly efficient.

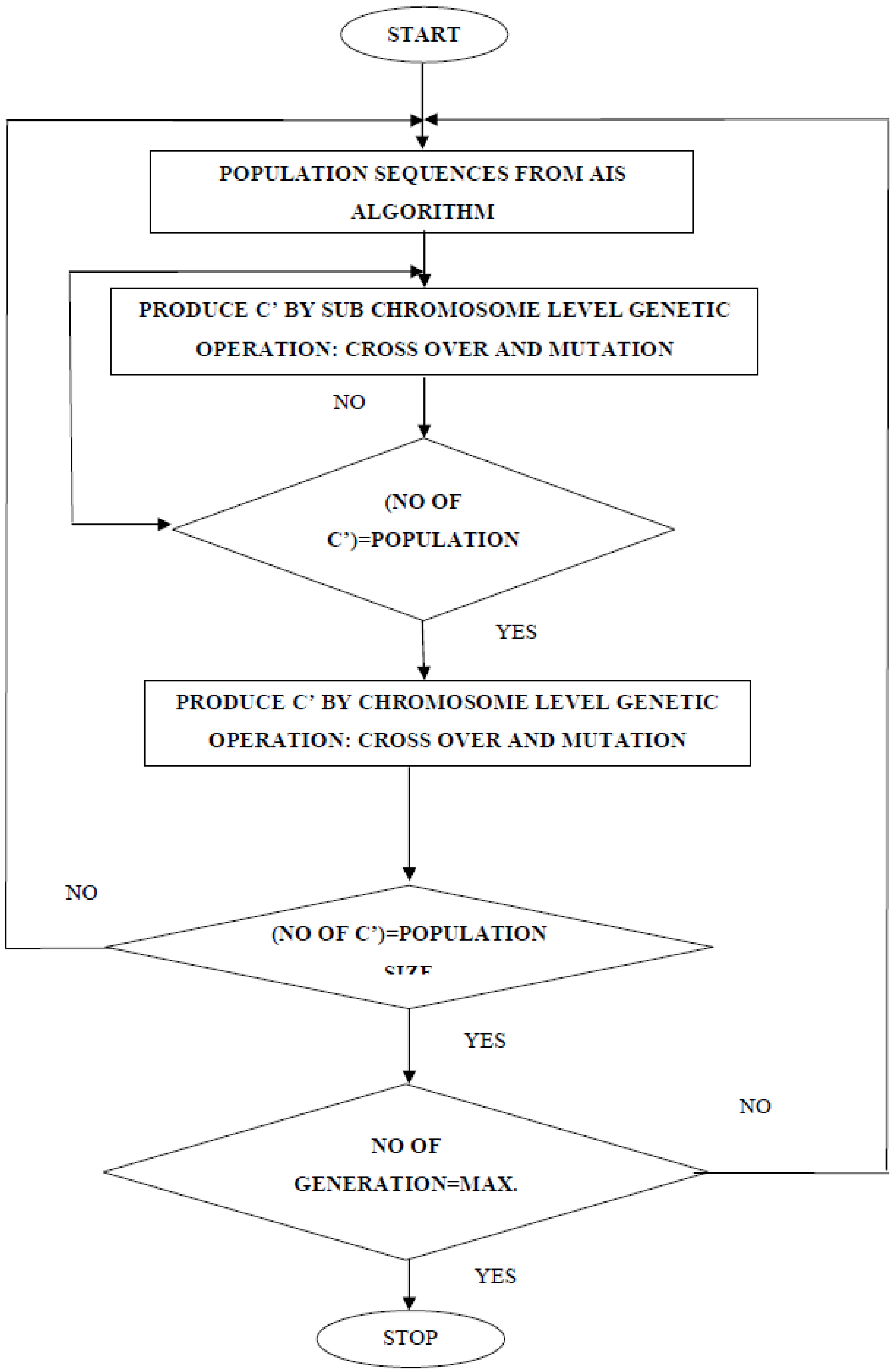

FIG.3 PROPOSED HYBRID SFHM ALGORITHM FLOW DIAGRAM FOR JSP

The artificial immune system was based on the two immune system concepts listed below:

1. Principle of clonal selection

2. Principle of affinity maturation

Hierarchical genetic processes crossover & mutation are included into the algorithmic string structure of the heredity model for sheep herds. There is

a. genetic operation at the sub-chromosome level &

b. genetic operation at the chromosomal (global) level.

This hierarchical procedure is known as a "multistage genetic procedure."

TABLE 1. PROVIDES JSP 1 PROCESSING DURATIONS & DEADLINE DATES.

JSP1	Operation 1	Operation 2	Operation 3	Operation 4	Operation 5	Due Date
Job 1	13	16	19	7	14	37
Job 2	19	7	13	17	19	74
Job 3	19	18	16	18	19	111
Job 4	14	15	10	13	17	148
Job 5	8	8	19	7	9	185
Job 6	16	15	20	18	10	222
Job 7	14	17	18	5	20	259
Job 8	8	6	9	20	7	296
Job 9	16	13	9	16	12	333
Job 10	12	19	9	6	7	370

TABLE 2 ROUTING OF JSP 1 OPERATION

JSP1	Operation 1	Operation 2	Operation 3	Operation 4	Operation 5
Job 1	1	5	4	2	3
Job 2	4	5	2	1	3
Job 3	3	2	5	4	1
Job 4	1	4	5	2	3
Job 5	1	2	5	4	3
Job 6	3	2	5	4	1
Job 7	2	4	3	1	5
Job 8	1	2	4	5	3
Job 9	5	4	3	2	1
Job 10	2	1	3	5	4

9. RESULTS & DISSCUSSION

For multi objective scheduling, the hybrid SFHM & AISSB algorithms are applied to optimize makespan, mean tardiness & mean flow time of 2 benchmark JSP instances provided by BAGCHI (1999). The first issue designated as JSP1, is a ten-job, five-machine instance. The second challenge, designated JSP2, is a ten-machine & ten-job instance. Finding non-dominated solutions with the Naive & Slow approach leads to Pareto optimal solutions. The hybrid SFHM algorithm seems to minimize all objectives at the same time, & also the outcomes are contrasted to those of the Genetic Algorithm. The outcomes of the computational study showed that the suggested hybrid SFHM algorithm is a good way to solve the multi-objective JSP problem.

TABLE 3. RESULTS FROM A HYBRID SFHM/AISSB/GA METHOD FOR JSP 1

S.N.	GA				AISSB				HYBRID SFHM			
	M.S (MAKE SPAN)	M.F.T (MEAN FLOW TIME)	M.T (MEAN TARDINESS)	COF (COMBINED OBJECTIVE FUNCTION)	M.S	M.F.T	M.T	COF	M.S	M.F.T	M.T	COF
i.	156	128.4	10.8	0.926	136	113.56	9.69	0.6	135	113.56	8.69	0.57
ii.	158	126	8.2	0.903	140	100.92	7.09	0.63	138	100.92	8.09	0.56
iii.	159	124.3	15.7	0.622	145	111.86	12.9	0.53	143	111.86	12.9	0.49
iv.	159	127.3	7.8	0.773	146	101.23	7.3	0.57	143	101.23	7.09	0.48
v.	160	124.3	13.9	0.630	150	111.18	11.9	0.58	148	111.18	10.9	0.46
vi.	162	130.5	6.4	0.672	154	100.72	5.4	0.46	153	100.72	5.04	0.42
vii.	165	128.8	6.4	0.867	151	119.66	5.8	0.5	155	109.66	5.28	0.41

viii.	167	122.4	15.1	0.629	154	112.36	10.69	0.59	152	112.36	9.69	0.49
ix.	169	134.5	6.1	0.683	160	109.95	5.04	0.51	160	102.95	4.94	0.44
x.	182	135.4	5.8	0.632	169	100.95	5.4	0.41	163	99.9	5.2	0.31

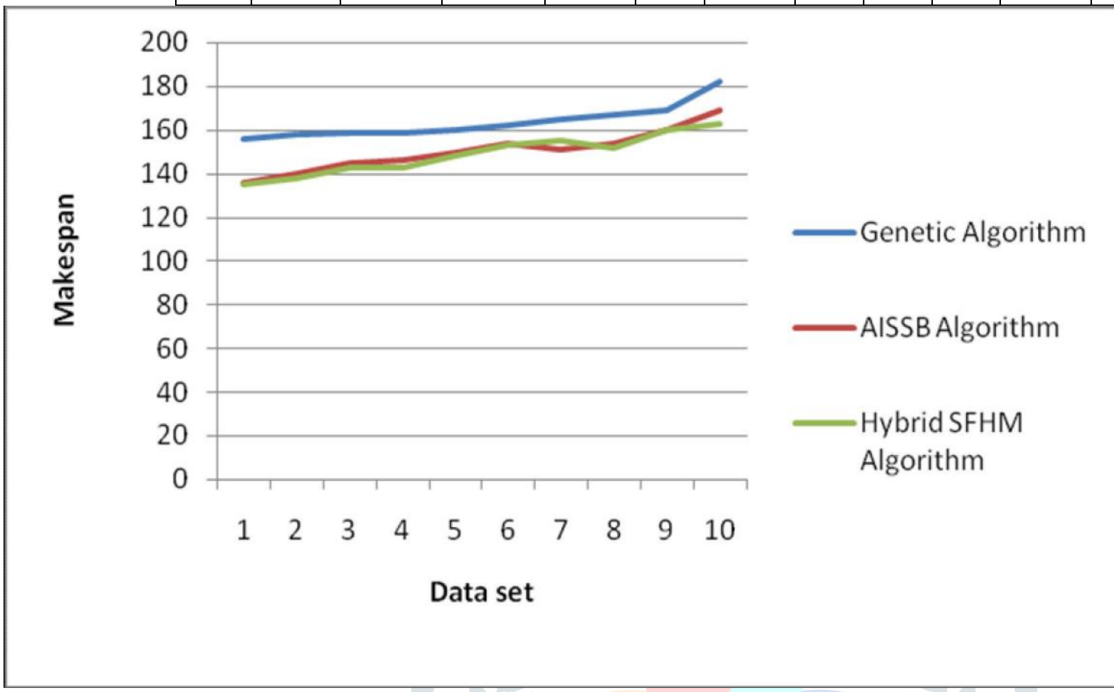

Fig 4 MAKESPAN vs. GENETIC ALGORITHM, AISSB ALGORITHM, & HYBRID SFHM ALGORITHM COMPARISON ON JSP1

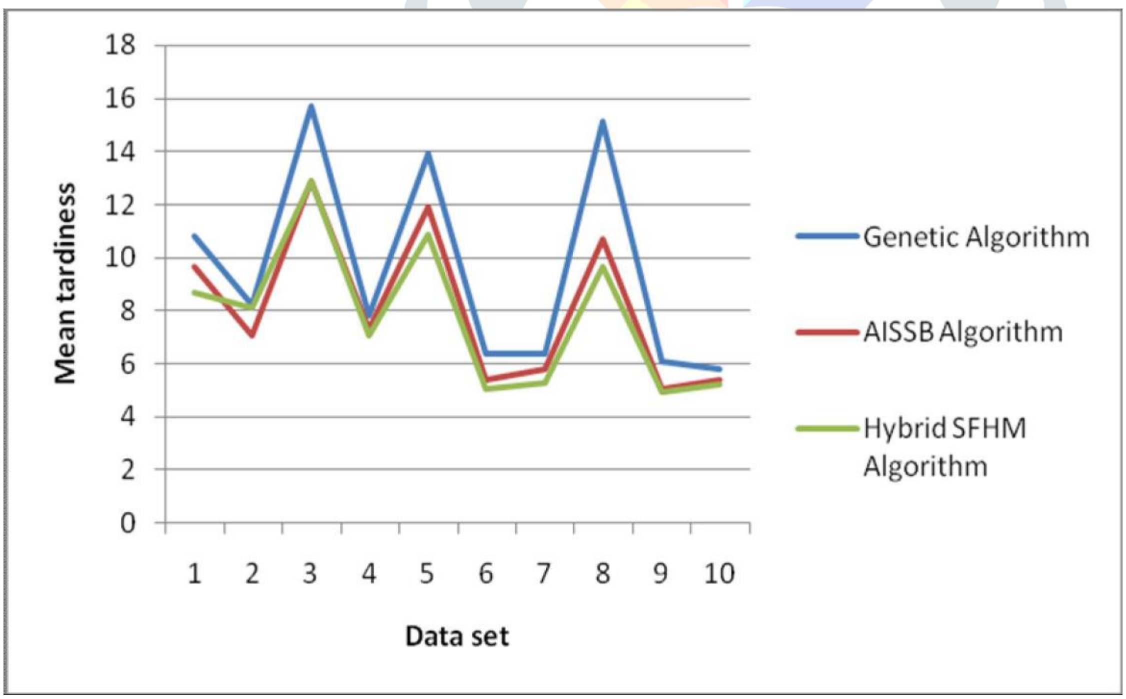

FIG 5 EVALUATION OF MEAN TARDINESS FOR JSP1 USING GENETIC ALGORITHM, AISSB ALGORITHM, & HYBRID SFHM ALGORITHM

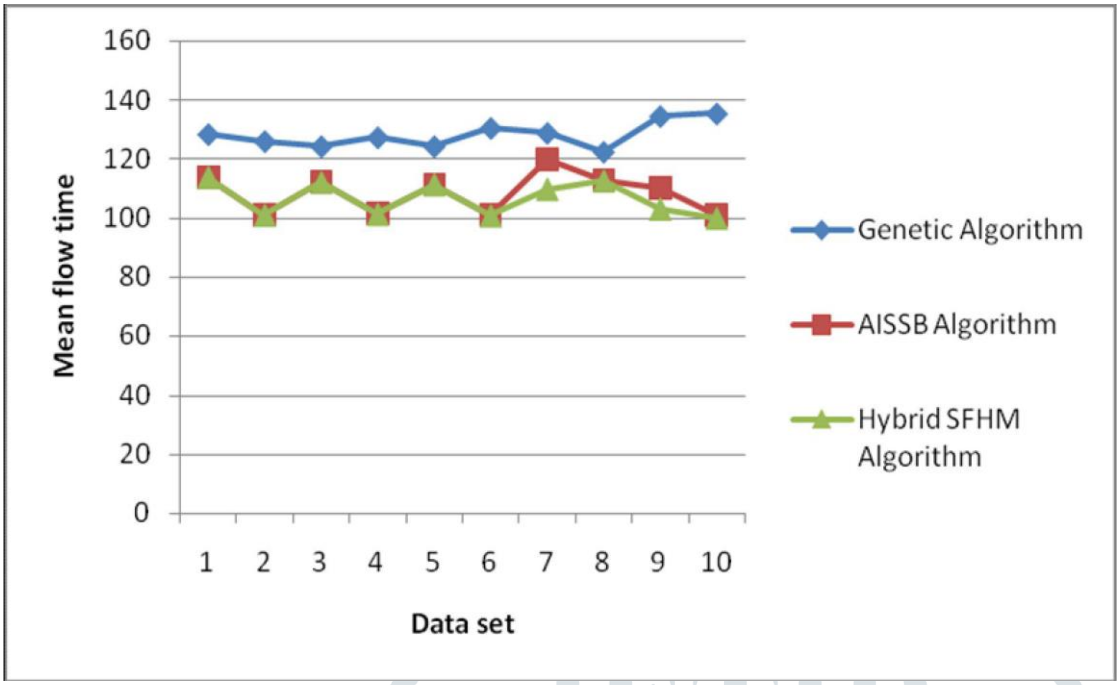

FIG. 6 EVALUATION OF MEAN FLOW TIME FOR JSP1 WITH THE GENETIC ALGORITHM, THE AISSB ALGORITHM, AS WELL AS THE HYBRID SFHM ALGORITHM

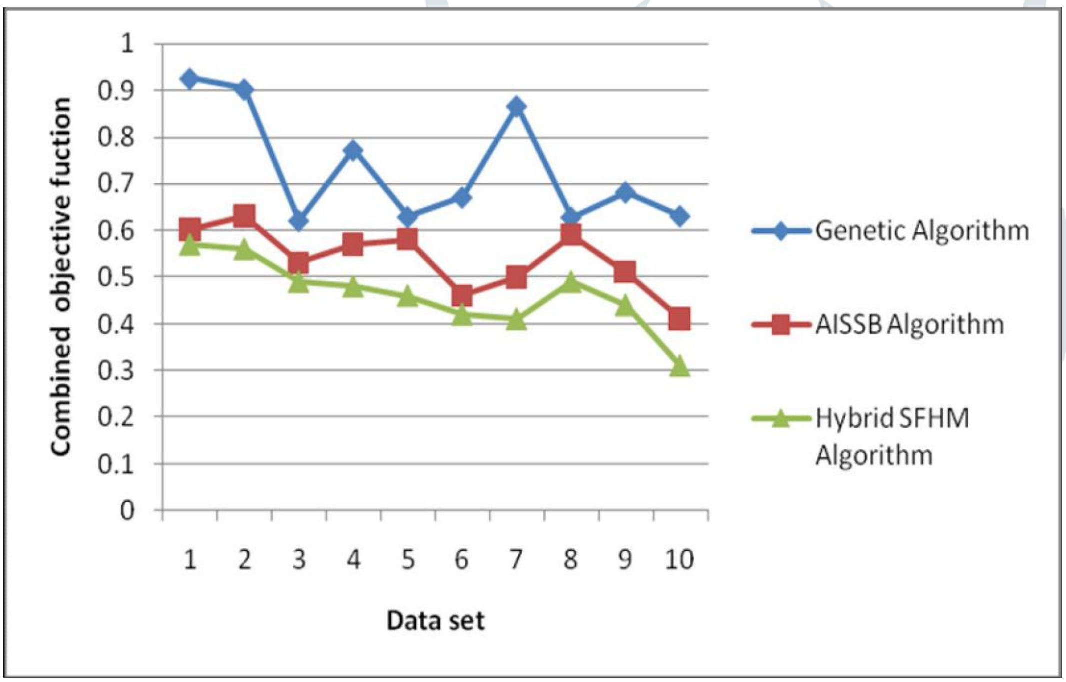

FIG.7 COMPARATIVE ANALYSIS OF THE COF WITH THE GENETIC ALGORITHM, THE AISSB ALGORITHM, AND THE HYBRID SFHM ALGORITHM FOR JSP1

10. CONCLUSION

The focus of this study was on issues that arise in the context of job shop scheduling. The author of this study provides near-optimal solutions to these issues for a range of problem sizes. This study has taken into account the multi-objective model while scheduling the job shop. Job shop scheduling issues with the goal of minimizing makespan, mean flow time, & mean tardiness are investigated. Various hybrid heuristic techniques, such as Artificial Immune System Shifting Bottleneck (AISSB) Algorithm & Hybrid Sheep Flocks Heredity Models (SFHM) Algorithm, are put to the test using multi-objective JSP 1 and JSP 2 issue situations. Using the Naive & Slow technique, a collection of Pareto-optimal solutions was discovered. The results are contrasted to Genetic Algorithm's examination of the identical issues (Garen 2004). The performance of the hybrid SFHM algorithm is superior to all other heuristic techniques used to evaluate the identical challenges. The suggested hybrid SFHM algorithm is capable & proved to be an effective problem-solving method for multi-objective scheduling optimization. Important criterion of a production system is customer satisfaction via on-time task completion. Hybrid heuristic algorithms have been developed in this study to solve job shop scheduling benchmark issues with quality outcomes. Two novel hybrid heuristic techniques for job shop scheduling are developed. The Hybrid SFHM technique has earned a reputation as a robust optimization tool that outperforms direct & heuristic approaches.

11. FUTURE SCOPE OF WORK

I. In future projects, job shop scheduling will be integrated with process planning as well as other production areas.

II. In addition to flow shop scheduling and FMS scheduling, the hybrid heuristic techniques established in this study may be used to a wide variety of additional scheduling scenarios.

III. Cost is only one of many potential objectives in multi-objective optimization.

IV. It is possible to perform tests on industrial data in real time.

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