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Genetic Algorithm Based Hybrid Approach to Solve Multi-Objective Assignment Problem

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ABSTRACT: Assignment problem (AP) deals with the allocations of n-tasks to n-resources into a pattern in such way that the total decision parameter can be optimized. An assignment problem may appear as an optimization problem with a multiple objectives. In multi-objective assignment problem (MOAP), an important research concern with the study of efficient solution. In MOAP, the set of efficient solutions can be very large; many of them are not worth to be determined. So in this paper, we present a solution procedure of multi-objective assignment problem using genetic algorithm based hybrid approach. The developed hybrid approach also shows that the influences of the convergence to efficient solution of MOAP of when different weights are given by decision maker (DM).

KEYWORDS: Assignment problem, MOAP, fuzzy linear membership function, Genetic algorithm.

I. INTRODUCTION

In many important area of decision making, the structure of assignment problem is popular subject of the study and important research tool. An assignment problem deals with assigning N resources to N tasks so that given measure of effectiveness is optimized. This nature of the problem can be found in many important application areas such as resources allocation, manpower deployment, scheduling, planning, grouping etc [13].

In AP, N number of workers must assign to N number of tasks where each worker has to complete their individual assigned task. However, due to personal ability or other reasons, each worker may spend a different quantity of resources to complete different tasks. The objective is to assign each task to a proper worker so that the total utilization of resources can be completed and all tasks can be minimized [2]. Generally, in AP, two types of cases are considered: Maximize objective, and Minimized objective. In minimization problem aims to finding the optimal assignment that minimize the total mission cost or the total complete mission duration etc whereas the maximization problem used for search the optimal assignment that maximize the overall profit of manufacture or the overall sale of manufacture etc [13]. Real world application of assignment problems involves many objectives like minimization of completion time, total assignment cost, maximize the overall profit, maximize the overall sales etc. For the assessment and comparison of the alternatives a single objective is not often sufficient to embrace all facets of the problem. So, the assignment problems also involve multiple objectives. In multi-objective assignment problem, there is frequently a conflict between the different objectives to optimize simultaneously. For example, in bi-objective assignment problem, one objective is fully satisfy, results in only partially satisfaction of other [3].

II. RELATED WORK

Many researchers focus on solution of MOAP and try to provide better solution. Anthony Przybylski et al. [14] developed a two phase method for multi-objective integer programming and its application to the assignment problem with three objectives. Chiao-Pin Bao et al. [2] has developed an approach to study the multi-objective assignment problem. They provide a simple method for solving the problem. Ahmed Bufardi [3] (2008) developed an approach for

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find efficiency of feasible solution of a multi-criteria assignment problem'. This paper addresses the problem of efficiency of feasible solution of a multi-criteria assignment problem. It is done in two steps. In first step, a give feasible solution of multi-criteria assignment problem is efficient or not and in second step, if the feasible solution is not efficient then they provided an efficient solution that dominates it. Kagade K. L. and Bajaj V. H. [11] (2009) developed a Fuzzy approach with linear and some non-linear membership functions for solving multi-objective assignment problems. This latter also provided the comparison between the result obtained by using linear and non-linear membership functions. Ibrahim Giingor and Mustafa gunes [9] (2000) try to solve Fuzzy Multiple-criteria Assignment Problems for fusion the case of Hungarian algorithm. Tsai, Chiu-Chi Wei and Ching-Liang Cheng [20] (1999) have solved a multi-objective assignment problem associated with cost, time, and quality by using Fuzzy approach. P.K.De and Bharti Yadav [12] (2011) have solved the multi-objective assignment problem by using interactive fuzzy goal programming approach. Hadi Basirzadeh, Vahid Morovati, Abbas Sayadi [7] (2014) have developed a quick method to calculate the super-efficient point in multi-objective assignment problems also provided how to obtain the best non-dominated point (the point having the least distance to the ideal point) for the multi-objective assignment problems which is more efficient and is so quick while simple, compared with other similar methods in other studies. Pankaj Gupta and Mukesh Kumar Mehlawat [13] developed a fuzzy approach to multi-criteria assignment problem using exponential membership functions.

In this paper, we defined the solution procedure of multi-objective assignment problem by genetic algorithm based hybrid approach. It also shows that the influences of the convergence to efficient solution of MOAP of when different weights are given by decision maker.

The rest of the paper proceeds are as follows: in section-3, we defined the model of MOAP. We developed a solution methodology of multi-objective assignment problem in section-4. In section-5, numerical illustration and result analysis are presented. Comparison of the proposed approach with different approach is derived in the section-6. Conclusions are presented in section-7.

III. MULTI-OBJECTIVE ASSIGNMENT PROBLEM

A. MODEL OF MULTI-OBJECTIVE ASSIGNMENT PROBLEM:

Model of multi-objective assignment problem is defined as follows [2, 3, 7, 9, 11, 12, 13, 14,20]:

$$\min Z^k(x) = \sum_{i=1}^n \sum_{j=1}^n c_{ij}^k x_{ij}, k=1, 2 \dots m$$

Subject to:

$$\sum_{i=1}^n x_{ij} = 1; j=1, 2, 3 \dots n \text{ (only one person should be assigned the } j^{th} \text{ job)}$$

$$\sum_{j=1}^n x_{ij} = 1; i=1, 2, 3 \dots n \text{ (only one job is done by the } i^{th} \text{ person)}$$

$$x_{ij} \in \{0,1\}; i, j = 1 \dots, n$$

$x = (x_{11}, x_{22}, \dots, x_{nn})$ is the matrix of decision variables.

(1)

$$x_{ij} = \begin{cases} 1; & \text{if } i^{th} \text{ assignee perform to } j^{th} \text{ task} \\ 0; & \text{else} \end{cases}$$

x_{ij} denotes that j^{th} job is to be assigned to the i^{th} person.

Indication of "min" word: there does not necessary to exist a solution having the minimum value with respect to each objective function and definitely the "efficient" solution will depend on the trade-offs between the different objective functions.

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B. FUZZY LINEAR MEMBERSHIP FUNCTION:

Literature says data can be normalized by dividing each data of the problem by its maximum number or by applying the fuzzy linear membership function or dividing by its statistical measure [1]. In this paper, we have utilized standard fuzzy linear membership function for normalization which is as follows.

Let L_k and U_k are minimum and maximum value of objective Z_k then fuzzy linear membership function is defined as follows:

$$\mu_k(x_{ij}^k) = \begin{cases} 0 & x_{ij}^k \leq L_k \\ \frac{x_{ij}^k - L_k}{L_k - U_k} & L_k \leq x_{ij}^k \leq U_k \\ 1 & x_{ij}^k \geq U_k \end{cases} \quad (2)$$

IV. SOLUTION METHODOLOGY

Throughout the year, several researches have been developed the approaches for solution of MOAP by using genetic algorithm. Out of them Tuytens et al. [5] have proposed a multi-objective simulated annealing (MOSA) for solving the bi-criteria assignment problem. The latter provides good approximation of the set of efficient solutions in a reasonable time. Moreover, MOSA found its efficiency, especially for large scale problems. Reference [16] has proposed a hybrid genetic algorithm to solve bi-criteria assignment problem. The framework of this algorithm is a cooperative approach between genetic algorithm and linear programming method to generate the set of non supported efficient solutions of the problem and it also contains local search procedure to introduce for balancing the diversification and the intensification in the search area. Adiche [4] have developed a hybrid method for solving the multi-objective assignment problem. This paper provided metaheuristics method for solving multi-objective assignment problems with three or more objectives which is based on the dominance cost variant of the multi-objective simulated annealing (DCMOSA) and hybridizes neighborhood search techniques which consist of either a local search or a multi-objective branch and bound search. The Three-Index Assignment Problem (AP3) is studied by Gaofeng Huang et al. [8]. This latter proposed a new local search heuristic for AP3 and hybridized it with genetic algorithm. Toroslu and Arslanoglu [19] presented GA solutions for different versions of the personnel assignment problem with multiple objectives based on hierarchical and set constraints.

To find the solution of multi-objective interval assignment problem, we using genetic algorithm based hybrid approach. To define the sets and variables in an MOIAP, some notations are given as follows.

Let A is the set of n-persons as (A_1, A_2, \dots, A_n) .

B is the set of n-jobs as (B_1, B_2, \dots, B_n) .

Z is the set of m-objectives as (Z_1, Z_2, \dots, Z_m) .

The step wise description of developed hybrid approach for obtaining efficient solution of MOAP is as follows.

Step-1: Convert the multi-objective assignment problem into combine objective assignment problem (COAP).

Let $Z_k = [z_{kij}]$, where z_{kij} occupied resources to allocate worker i to job j in MOAP, for all $x_{ij} \geq 0$, for $i=1, 2 \dots n$, $j=1, 2 \dots n$, $k=1, 2 \dots m$.

Generally, two types of objectives measured in assignment problem:

1. Minimized objective
2. Maximized objective.

To convert the maximized and minimized objectives matrix $Z_k = [z_{kij}]$ into the matrix $C_k = c_{kij}$ using the following formulae:

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➤ for maximized objective:

$$C_k = L - z_{kij}; i, j = 1, 2, \dots, n \ \& \ k = 1, 2, \dots, m \tag{3a}$$

Where L is the maximum positive number, defined as $L = \max\{z_{kij}\}$

➤ for minimized objective:

$$C_k = c_{kij} = z_{kij}; i, j = 1, 2, \dots, n \ \& \ k = 1, 2, \dots, m \tag{3b}$$

Normalized matrix μ_k of $C_k = [c_{kij}]_{n \times n}$ is obtained as follows:

$$\mu_k = \mu_k(c_{kij}) = \begin{cases} 0 & c_{kij} \leq L_k \\ \frac{c_{kij} - L_k}{U_k - L_k} & L_k \leq c_{kij} \leq U_k ; \\ 1 & c_{kij} \geq U_k \end{cases} \tag{4}$$

In order to convert MOAP in COAP, find combined matrix A and defined as

$$A = \sum_{k=1}^m W_k \mu_k \tag{5}$$

Here W_k is weight for each objective function where $k = 1, 2, \dots, m$. Hence MOAP is converted into COAP.

Step-2: Use GA to solve the COAP which obtained in step-2 for assign n-worker to n-tasks.

Genetic algorithm is a most adaptive optimization search methodologies based on machine of natural genetics, natural selection and survival of fitness in biological system. It is work by mimicking the evaluating principle and chromosome processing in natural genetics [17]. It is an iterative process which maintains a population of feasible solutions (known as chromosomes). It defines the fitness function to measure the chromosomes which is directly related to the objective function of AP. In each iteration, applying the three operators similar to natural genetics as selection, crossover and mutation to generate the new population. Selection process is forming a parent population for creating the next generation. Crossover process is the process of selecting two parents of chromosomes and produces a new offspring chromosome. Mutation process is process with mutation rate randomly alter selected positions in a selected chromosome. [17]. GA works with a population of solutions iteratively by sequentially applying these three basic genetic operators in each iteration (known as generation) until some termination condition is satisfied.

In order to form of solution of COAP by genetic algorithm, it is necessary to consider data structure of chromosome which represents the solution of problem in encoding space [18]. In case of COAP for N=4, the chromosome structure can be represented as follows:

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Here first row is equivalent to 8 in based 10, similar second and third rows decodes to 4, 2 and 1 respectively [18]. So, it is equivalent that each component in the string can be uniquely expressed as 2^r ; where r is real value varying from 0 to N-1. Hence the above COAP can be encoded as <8, 4, 2, 1>. Thereafter, the fitness function according to problem is evaluated. Then selection operator is proposed to improve the average quality of the population for the next generation by giving the high quality chromosomes a better chance to get copied into. In this approach we have used tournament selection [17, 18]. This process repeated population size times. Thereafter crossover operator is utilized. The objective of crossover operator is to produce children for the next population by exchange information between two parent's chromosomes. For that we present a partially matched crossover (PMX) [17, 18]. For example:

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Suppose the crossover between two permutations of the string <8, 4, 2, 1> and <1, 2, 8, 4>. Suppose the two crossover points have been chosen as shown below where dashed position show the chosen point.

```

8  4  2  1
   |  |
   ---
1  2  8  4

```

PMX defines the following scheme for interchanging $4 \leftrightarrow 2$, $2 \leftrightarrow 8 \leftrightarrow 4 \leftrightarrow 8$. Now, section between the selected crossover points is swapped and the rest of the other values are changed according to the above rule. So, two new offspring's strings are <4, 2, 8, 1> and <1, 4, 2, 8>. After crossover, the threshold is constructing. We have parenthood population and childhood population out which they are selected for the new iteration. To maintain the diversity in population, here we divide the population in four categories: those having values above $\mu + 3*\sigma$, values between $\mu + 3*\sigma$ and μ , values between μ and $\mu - 3*\sigma$, and values less than $\mu - 3*\sigma$. The whole population is arrange in ascending order according to their objective function value and choose predetermined individual strings from each category. In this way the best string cannot be escaped. After constructing the threshold, mutation operator is applied. For mutation, two random spots are chosen in a string and swapping corresponding values at position. For example: If we swap the string value <8,4,2,1> at second and fourth position then the new mutate string become <8,1,2,4>. At the end termination criteria of algorithm is decided. After developing the steps of GA, two cases are implemented for find the solution of the COAP: 1) with mutation 2) without mutation. In cases of the mutation, there is higher chance to reach the solution of the problem in minimum iteration [18].

ALGORITHM

Input: Parameters: $(Z_1, Z_2, \dots, Z_m, n)$

Output : To find the solution of MOAP

Solve MOAP $(Z_k \downarrow, X \uparrow)$

begin

read: example

while example = MOAP **do**

for $k=1$ to m **do**

enter matrix Z_k

end

-/ convert the maximization problem into minimization problem.

for $k=1$ to m **do**

Minimization $(Z_k) \leftarrow$ maximum number of $(Z_k) - Z_k$

end

-/ Divided each objective by its membership function for normalized data of each objective respectively.

for $k=1$ to m **do**

$$\mu_k = \mu_k(z_{kij}) = \begin{cases} 0 & z_{kij} \leq L_k \\ \frac{z_{kij} - L_k}{U_k - L_k} & L_k \leq z_{kij} \leq U_k \\ 1 & z_{kij} \geq U_k \end{cases}$$

-/ find combine matrix to convert the MOAP in COAP.

for $j=1$ to $n*n$

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$$A = \sum_{k=1}^m w_k \mu_k$$

end

|- find the solution of COAP using GA

Procedure: GA

Begin

Generation=0;

P= Generate the initial population of solution.

For ($X \in P$)

Evaluate Z(X); (Z(X) is objective function of X.)

end

While (Stopping criterion not met)

{Generation=Generation+1;

Begin

-| Apply tournament selection;

For $P' \in P$

P'=select fitness individual from P for matting pool according to tournament selection.

$P'' = \phi$

end

Repeat (Until enough children produced)

For $P_1, P_2 \in P'$

Select P_1 and P_2 from P' .

Apply the Partially matched crossover on P_1 and P_2 for produced new offspring.

$P'' = P'' \cup X \text{ child ;}$

end

Repeat

For $X \in P''$

Make a threshold, to keep the best individuals.

end

For $X \in P''$

Apply inversion on X.

End (Begin)

$P=P'';$

end (while)

end (Begin)

end

V. NUMERICAL ILLUSTRATION AND RESULT ANALYSIS

In this section, we present numerical illustrations of the multi-objective assignment problem. The developed hybrid approach is coded in MATLAB and all tests are carried out on an Intel (R)-core i5 CPU@ 2.60 GHz computer with 4 GB of RAM. The following settings of the parameters are used to solve different problem instances: number of tasks (n) = number of workers (n) = 3, number of objective = 2.

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Table-1 provided the necessary data in respect of cost and time [2, 11, 12]. An efficient solutions of MOAP are reported in the Table-2, 3, 4 for different weight which given by decision maker. We presented the results by taking different weights (w_1, w_2) .

Figure-1, 2, 3 shows that, the influences of the convergence to efficient solution of MOAP of cost and time when different weights are given by decision maker. Generally In multi-objective optimization problems, there rarely exists a solution that is optimal with respect to all objective functions. Most of time there often exist conflicts between the different objectives to be optimized simultaneously. If such a particular case arises then only solutions that are optimal with respect to each objective function are efficient. In Figure-1, 2, 3 there are two cases are implemented: one in which mutation is used and another in which mutation is not used. In both the cases, the answer converged to the final efficient solution.

Table-1: Cost-Time Matrix

Task j	Worker i		
	1	2	3
c_{1j}	10	8	15
t_{1j}	13	15	8
c_{2j}	13	12	13
t_{2j}	10	20	12
c_{3j}	8	10	9
t_{3j}	15	10	12

Table-2: Assignment plan-1

$w_1 = 0.5, w_2 = 0.5$			
With Mutation		Without Mutation	
Cost Z_1 :	30	Cost Z_1 :	30
Time Z_2 :	37	Time Z_2 :	37
Optimal allocations:		Optimal allocations:	
Worker-1: {Task-2}		Worker-1: {Task-2}	
Worker-2: {Task-1}		Worker-2: {Task-1}	
Worker-3: {Task-3}		Worker-3: {Task-3}	

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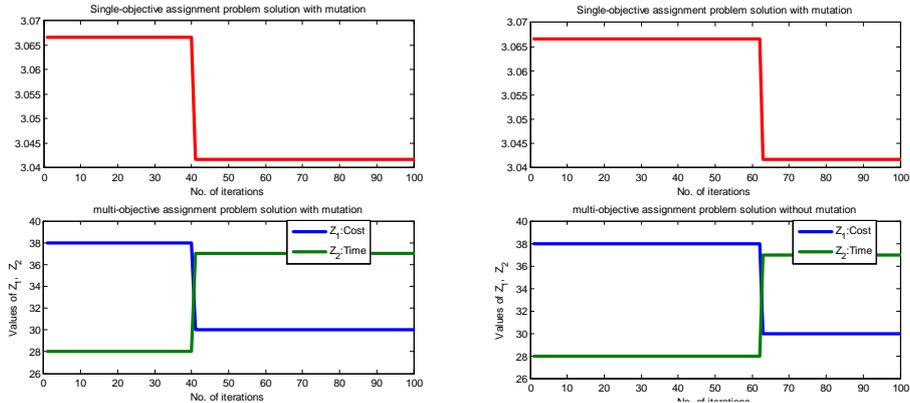


Figure-1: convergence to the global minimum in case of mutation and without mutation for COAP and MOAP when $w_1 = 0.5, w_2 = 0.5$.

Figure-1 shows that, the efficient solution of COAP and MOAP in case of using mutation operator and without using the mutation operator when $w_1 = 0.5, w_2 = 0.5$. In case of using mutation operator solution of COAP and MOAP is converges after 40 iterations else solution in both cases is converges after 60 iterations. Figure–1 also provides other alternatives solution to DM as per their requirement.

Table-3: Assignment plan-2

$w_1 = 0.1, w_2 = 0.9$			
With Mutation		Without Mutation	
Cost Z_1 :	38	Cost Z_1 :	38
Time Z_2 :	28	Time Z_2 :	28
Optimal allocations:		Optimal allocations:	
Worker-1: {Task-3}		Worker-1: {Task-3}	
Worker-2: {Task-1}		Worker-2: {Task-1}	
Worker-3: {Task-2}		Worker-3: {Task-2}	

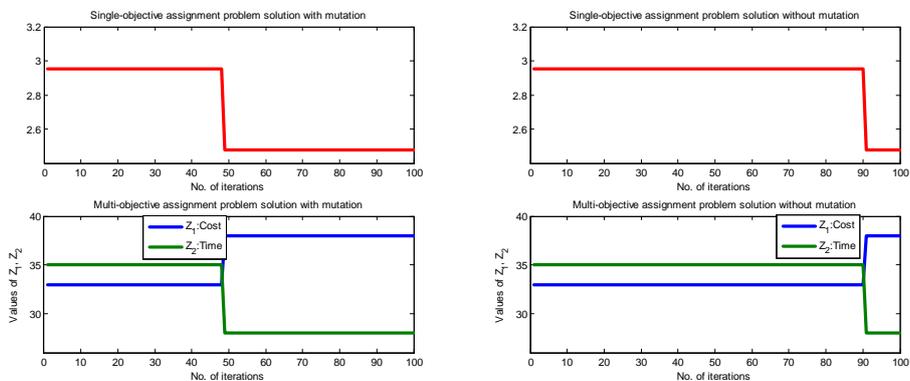


Figure-2: convergence to the global minimum in case of mutation and without mutation for COAP and MOAP when $w_1 = 0.1, w_2 = 0.9$.

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Figure-2 shows that, the efficient solution of COAP and MOAP in case of using mutation operator and without using the mutation operator when $w_1 = 0.1, w_2 = 0.9$. In case of using mutation operator solution of COAP and MOAP is converges after 50 iterations else solution in both cases is converges after 90 iterations. Figure–2 also provides other alternatives solution to DM as per their requirement.

Table-4 Assignment plan-3

$w_1 = 0.9, w_2 = 0.1$			
With Mutation		Without Mutation	
Cost Z_1 :	29	Cost Z_1 :	29
Time Z_2 :	42	Time Z_2 :	42
Optimal allocations:		Optimal allocations:	
Worker-1: {Task-2}		Worker-1: {Task-2}	
Worker-2: {Task-3}		Worker-2: {Task-3}	
Worker-3: {Task-1}		Worker-3: {Task-1}	

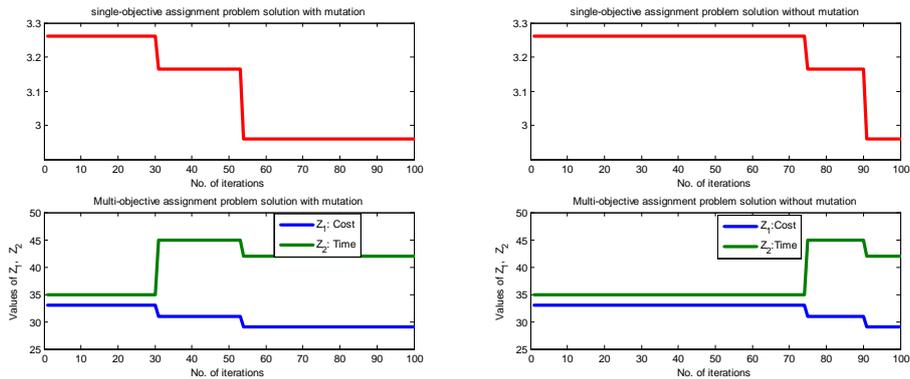


Figure-3: convergence to the global minimum in case of mutation and without mutation for COAP and MOAP when $w_1 = 0.9, w_2 = 0.1$.

Figure-3 shows that, the efficient solution of COAP and MOAP in case of using mutation operator and without using the mutation operator when $w_1 = 0.9, w_2 = 0.1$. In case of using mutation operator solution of COAP and MOAP is converges after 55 iterations else solution in both cases is converges after 90 iterations. Figure–3 also provides other alternatives solution to DM as per their requirement.

Another numerical example [1, 19]:

		Task j					
		1	2	3	4	5	6
Doers i	1	1	2	3	4	5	6
		6	3	5	8	10	6
		4	20	9	3	8	9
	2	1	3	1	1	1	5
		6	4	6	5	9	8
		6	18	8	7	17	8
	3	3	5	3	5	7	5
		11	7	4	8	3	2
		2	8	20	7	15	7
	1	7	5	3	5	7	

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	4	9	10	8	6	10	4
		12	13	14	6	9	10
		5	9	3	5	7	3
	5	4	6	7	9	8	7
		9	8	7	14	5	9
		3	9	7	5	3	3
	6	3	5	11	10	12	8
		17	13	3	4	13	7
		3	3	5	7	5	7

Table-6: The cost, time and quality assignment problem
Cost unit: Thousands, Time unit: weeks, Quality level: 1, 3, 5, 7, 9

Table-7 shows that the efficient solutions of MOAP of above problem.

Table-7: Assignment plan

$w_1 = w_2 = w_3$			
With Mutation		Without Mutation	
Cost Z_1 :	42	Cost Z_1 :	42
Time Z_2 :	41	Time Z_2 :	41
Quality Z_3 :	14	Quality Z_3 :	14
Optimal allocations:		Optimal allocations:	
Worker-1: {Task-4}		Worker-1: {Task-4}	
Worker-2: {Task-3}		Worker-2: {Task-3}	
Worker-3: {Task-1}		Worker-3: {Task-1}	
Worker-4: {Task-6}		Worker-4: {Task-6}	
Worker-5: {Task-5}		Worker-5: {Task-5}	
Worker-6: {Task-2}		Worker-6: {Task-2}	

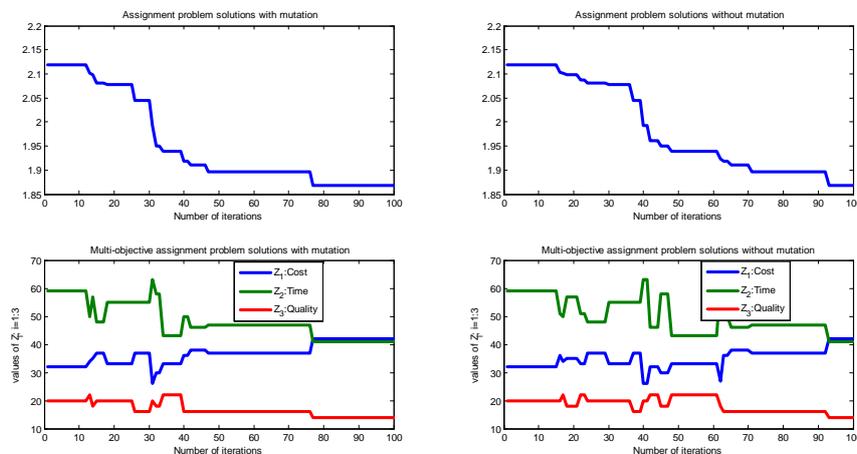


Figure-4: convergence to the global minimum in case of mutation and without mutation for COAP and MOAP

Figure-4 shows that, the efficient solution of COAP and MOAP in case of using mutation operator and without using the mutation operator when weights are equal for each objective. In case of using mutation operator solution of COAP

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and MOAP is converges after 75 iterations else solution in both cases is converges after 90 iterations. Figure–4 also provides other alternatives solution to DM as per their requirement.

VI COMPARISON OF THE PROPOSED APPROACH WITH THE DIFFERENT APPROACH

To further review of the developed hybrid approach, we compare the experimental results of the developed hybrid approach of Table-1 with the experimental result produced by the other approaches.

Table-8: comparison of developed hybrid approach and other approaches of Table-1

New Approach of Chiao-Pin Bao et al. [2]	developed hybrid approach
Cost Z_1 : 30 Time Z_2 : 37 Worker-1: {Task-2} Worker-2: {Task-1} Worker-3: {Task-3}	Cost Z_1 : 30 Time Z_2 : 37 Worker-1: {Task-2} Worker-2: {Task-1} Worker-3: {Task-3}

We also compare the experimental results of the developed hybrid approach of Table -6 with the experimental result produced by the developed hybrid approach and approach of Tsai et al.

Table-9: comparison of developed hybrid approach and other approaches of Table-6

New Approach of Chiao-Pin Bao [2]	developed hybrid approach
Cost Z_1 : 42 Time Z_2 : 41 Quality Z_3 : 14 Worker-1: {Task-4} Worker-2: {Task-3} Worker-3: {Task-1} Worker-4:{Task-6} Worker-5:{Task-5} Worker-6:{Task-2}	Cost Z_1 : 42 Time Z_2 : 41 Quality Z_3 : 14 Worker-1: {Task-4} Worker-2: {Task-3} Worker-3: {Task-1} Worker-4:{Task-6} Worker-5:{Task-5} Worker-6:{Task-2}

Table-8, 9 shows that proposed hybrid approach provide alternative approach to find the solution of MOAP when different weights are given by DM.

VII CONCLUSION

In this paper, an experimental analysis for solving the multi-objective assignment problem using hybrid approach based Genetic Algorithm is presented in which assignment plans also have been reported with respect to many choice of different weight of the decision maker. Paper also describes various parameters affect on algorithms and their influence on convergence to the final efficient solution.

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