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A MULTIPLE KNAPSACK APPROACH FOR ASSIGNMENT PROBLEM OF HUMAN RESOURCES

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ABSTRACT

In this paper, we propose the assignment problem of resources humans' methodology by using the multiple knapsack approach to formulate the studied problem, and solve it by using the genetic algorithm for obtaining the optimal assignment of the new qualified employees that ensures the maximization the productivity by introducing constraints corresponding to the cost of each posts, and capacity of personnel in each service of enterprise. The personnel selected can be transferred and diversifying their competencies and qualifications. This study of this problem allows the managers of human resources to manage the recruitment of qualified employees to occupy the posts in of enterprise for improving the productivity. The multiple knapsack problems (MKP) is a more complex variant of the 0–1 knapsack problem, an NP-Hard problem So, our problem is difficult combinatorial problems Finally, a detailed algorithm based on the GA will be presented as a method of solving our problem with a numerical example to valid this work.

Keywords: *Multiple Knapsacks Problem, Assignment Problem, Genetic Algorithm*

1. INTRODUCTION

Human resources are considered as one of the most important sources of today's enterprise. Human resources management is more important than other competitive sources since these people use other assets in organization, create competitiveness and realize objectives [1]

In addition, the key functions of the Human Resources Management (HRM) team include recruiting and mobility of the personal, motivating employees as well as workplace. The beneficial effects of good management of personnel assignment (recruiting and mobility) are discussed here [2]

The assignment problems are classical problems in operations research, where the simplest application is the assignment of m agent to m posts, where each couple (post, agent) has a cost In personnel assignment problem, the possible ways of assigning a set of personnel to available post from a set with the same cardinality are sought, while taking also into account the weights each personnel is given with respect to each position [3].

The objective of the standard assignment problem is to maximize the summation of the weights of the candidates, their individuals weights are measured during interviews by collection of information on candidates to be recruited by transferring and diversifying their competencies and qualifications. However, the bad selection of these candidates can influence negatively within multiple services in enterprise [5]

This work focuses on a model used to manage a real- human resource allocation problem involving allocating the persons qualified to occupy the new posts for maximizing the productivity of enterprise

This model is based on the multiple Knapsacks to formulate the studied problem. The (MKP) is a variant of 0-1 Knapsack problem [7-8]. Many applications of this NP-hard problem such as resource allocation [12] capital budgeting problem [14]. The resolution is the main objective of several works proposed by several researchers. We cite as an example: Chu and Beasley [10] and proposed a genetic algorithm to solve the (MKP), Li and all [11] who proposed a genetic algorithm based on the plane orthogonal to the (MKP).

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To solve our problem do this, we implement genetic algorithms; the resulting solution allows us to determine the optimal allocation of candidates to posts locating in different units of production in the enterprise to maximize the productivity.

This work that is which complements our work addressing the problem of mobility of human resources under constraints [1-3] is organized as follows: First we present an approach to optimize the recruitment of staff. The problem is NP hard and formalized. We will then introduce the AG to obtain the optimal solutions that validate this approach; we will comment and compare the results with summary tables and graphical results.

2. PRESENTATION OF THE PROPOSED APPROACH

2.1 Problem description

In this work, we are interested in studying an assignment problem such as recruitment problem of new employees to posts. This recruitment problem can be announced as follows: to recruit candidates with profiles depend on the needs of an enterprise multi-site or multi services leaders conducting recruitment tests which are tools that allow candidates to say thanks to standardized exercises (oral, written, computer..) that use specific processes and evaluations that aim to analyze the capacity of several candidates competing for the same position [19].

In these tests, we assume that any candidate is assessed by an individual weight may refer to his ability, experience, qualifications... etc. In addition, each candidate may choose a production site where it wants to move and each production site ready to welcome the selected candidates in order of preference. The problematic mainly resides in the answer to this question: how to select qualified candidates who will fill vacant posts subjected to certain budgetary costs, while improving the overall efficiency of production sites?

The recruitment approach in this section is based on a model of multidimensional knapsack. So, after the rapprochement between our problem and a of multiple knapsack problem, a dimension of a knapsack corresponds to a production site or service, and profiles of an object to put in a dimension of knapsack corresponds to individual weight of a candidate to recruit. The goal of this approach is to recruit and assign the qualified candidates to production sites to maximize the overall profile of the enterprise under the constraint of the budgetary costs and the capacity constraint.

2.2 Multiple knapsack Problem (MKP)

The *0/1* Multiple Knapsack problem consists of m knapsacks of capacities $c_1, c_2, c_3. c_j.. c_m$ where m and n objects, each of which has a profit p_j. Unlike the simple version in which the weights of the objects are fixed, the weight of the ith object in the Multiple Knapsack Problem takes j values, $1 \leq j \leq m$.

The i^{th} object weighs m_{ij} when it is considered for possible inclusion in the jth knapsack of capacity c_j in order to satisfy this formulation:

$$\begin{cases} \mathrm{Max}\left(\sum_{j=1}^{m}\sum_{i=1}^{n} p_j x_{ij}\right) & (1) \\ \sum_{i} m_i x_{ij} \leq c_j \ \forall\, 1 \leq j \leq m & (2) \\ \sum_{j} x_{ij} \leq 1 \ \forall\, 1 \leq i \leq n & (3) \end{cases}$$

The decision variable $X_{ij} \in \{0, 1\}$:

$$x_{ij} = \begin{cases} 1, \text{object } i \text{ is included in the KSP } j \\ 0, otherwise \end{cases}$$

We also note that it can be thought as a resource allocation problem, where we have m resources (the knapsacks) and n objects. Each resource has its own budget (knapsack capacity). We are interested in the following section to formulate the assignment problem with constraints as a Multiple Knapsack problem.

2.3 Formulation of the assignment problem

Based the correspondence established between our assignment problem and multiple knapsack problem, we can deduce the formulation of our problem. The notations used to formulate this assignment problem are presented follow:

- $U = \{\{U_j\} / j \in [1, NS]\}$: set of production sites;
- $I = \{1,2, \dots, i \dots, nc\}$: set of indexed employees or candidates;
- .$W(i)$: Wight of candidate i with $W(i) > W(i+1)$, $\forall\, i \in I$;
- W_j^{glo}: weight generated by N_j candidates ;
- W^{glo}: weight generated by all candidates ;
- $\tilde{N}_j$: number of candidates desiring to occupy the posts in production unit U_j;

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- N_j: number of candidates assigned to U_j ;
- n_j : number of vacant posts in U_j ;
- C_j : cost of all posts in U_j
- *Cost*: global matrix cost of post.

$$W = \begin{pmatrix} W_{11} & W_{12} & . & . & . & W_{1\tilde{N}_1} \\ W_{21} & W_{22} & . & . & . & W_{2\tilde{N}_2} \\ W_{31} & W_{31} & . & . & . & W_{2\tilde{N}_3} \\ . & . & . & . & . & . \\ W_{j1} & W_{j2}. & . & . & . & .W_{j\tilde{N}_j} \\ . & . & . & . & . & . \\ W_{m1} & W_{m2} & . & . & . & W_{m\tilde{N}_m} \end{pmatrix}$$

Figure 1 : The weight matrix of candidates

In this matrix, each row represents the weights W_{ji} of a class of candidates likely to be assigned to posts in the production site U_j. This process is similar to select the items of class j possessing the profiles P_{ji} to put them in the dimention j of the knapsack:

- X_{ij} is the decision variable given by:

$$X_{ij} = \begin{cases} 1, \text{if the candidate } i \text{ of class } j \text{ is assigned} \\ 0, otherwise \end{cases} \quad (5)$$

Also, the constraint costs are written as:

$$\sum_{\substack{j=1 \\ j\neq k}}^{NS} \sum_{i=1}^{\tilde{N}_j} c_{ij}\, x_{ij} \leq C_j \;\; \forall j \in [1, NS] \quad (6)$$

This constraint explains that the sum of the budgetary costs posts that will be occupied by candidates assigned (recruited) should not exceed the aggregate cost fixed by the manager.

$$Cost = \begin{pmatrix} C_{11} & C_{12} & . & . & . & C_{1\tilde{N}_1} \\ C_{21} & C_{22} & . & . & . & C_{2\tilde{N}_2} \\ C_{31} & C_{32} & . & . & . & C_{2\tilde{N}_3} \\ . & . & . & . & . & . \\ C_{j1} & C_{j2}. & . & . & . & .C_{j\tilde{N}_j} \\ . & . & . & . & . & . \\ C_{m1} & C_{m2} & . & . & . & C_{m\tilde{N}_m} \end{pmatrix}$$

Figure 2: The costs matrix of candidates

This constraint explains that a candidate can't have two posts simultaneously in U_j.

$$\sum_{j=1}^{NS} X_{ij} \leq 1 \;\forall\, i \in [1, \tilde{N}_j], \forall\, j \in [1, NS] \quad (7)$$

So, the global formulation of the recruitment problem is given by:

$$\begin{cases} Max\ F = max \sum_{j=1}^{NS} \sum_{i=1}^{\tilde{N}_j} W_{ij} X_{ij} \\ \sum_{\substack{j=1 \\ j\neq k}}^{NS} \sum_{i=1}^{\tilde{N}_j} c_{ij}\, x_{ij} \leq C_j \;\forall j \in [1, NS] \\ \sum_{j=1}^{NS} X_{ij} \leq 1 \;\forall\, i \in [1, \tilde{N}_j] \end{cases} \quad (8)$$

Based on the complexity of the Multiple Knapsack Problem known as an NP Hard problem, we can see that the assignment problem is also a NP Hard problem. An optimal solution to problem [12] can be obtained by a suitable resolution method. Generally, the resolution of instances is done through genetic algorithm include a heuristics seen to be effective in providing good solutions [13, 15].

3. GENETIC ALGORITHM OF RESOLUTION

3.1 Genetic algorithm

Genetic algorithms are metaheuristics search algorithms based on the mechanics of natural selection. The multiple knapsack problem (MKP) is a combinatorial optimization NP-Hard [18]. Several meta-heuristics have been developed to find, if not the optimal solution, a "good solution" to this problem, although sometimes the endpoint is under optimal local premises. We are therefore interested to solve the recruitment problem likened to the multiple knapsack problem using AG shows good performance on solving static optimization problems[16-17].

In our approach, we used as a real encoding method of representation, the binary representation of sub-matrix, each sub matrix is composed by lines vectors that can be encoded by an array of Booleans: *0* or *1*. This binary representation of solution we have adopted for the MKP allows a wide range of the GA matrix crossovers and matrix mutation operators to be adopted [3].

3.2 The proposed algorithm

The Genetic Algorithm proposed to solve the assignment problem is presented in the next figure:

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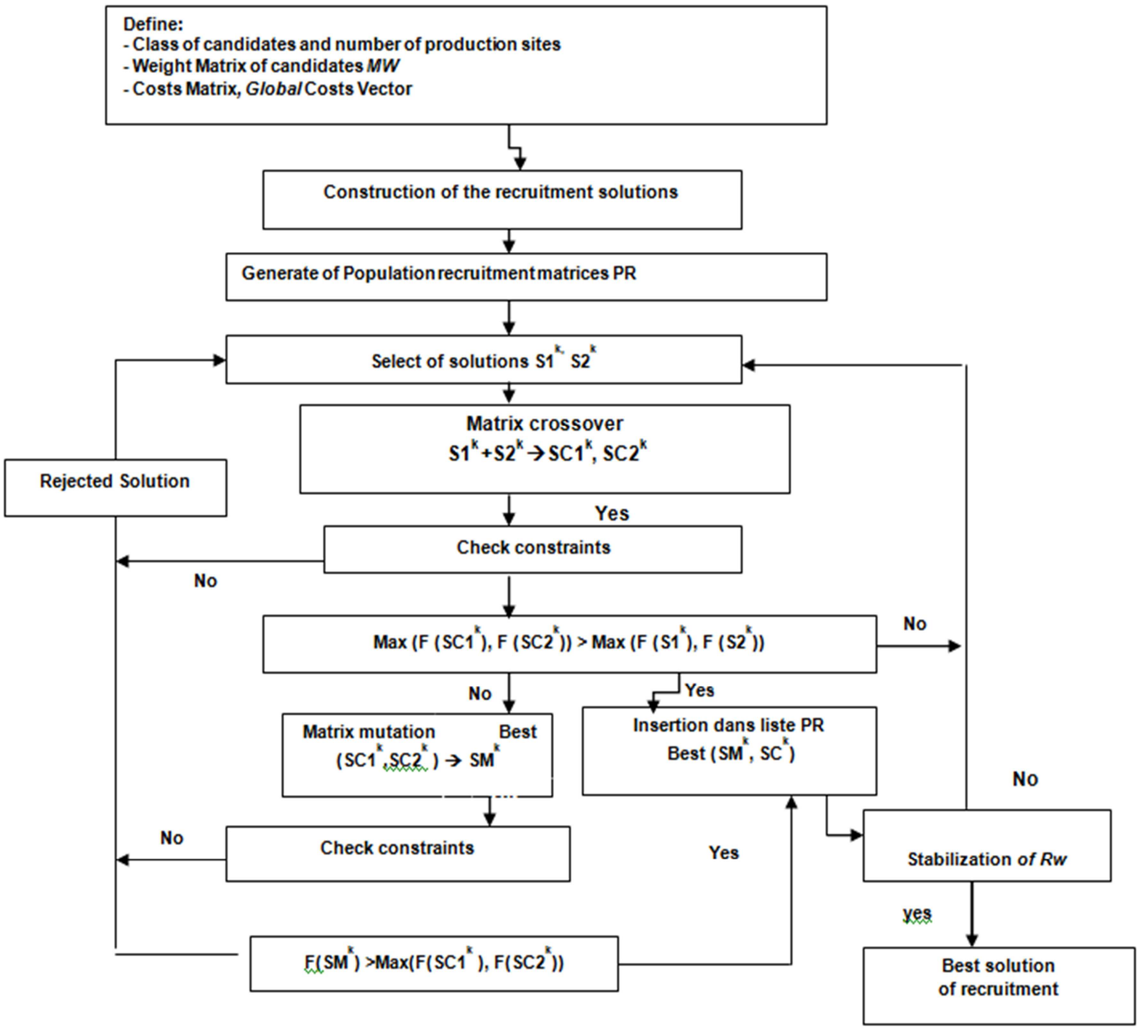

Figure 3: Algorithmic Diagram Of Proposed Assignment Approach

4. EXPERIMENT AND RESULTS

4.1 Description of the instance of the studied problem

In this section, we present an example to valid this approach by using the genetic algorithm disrupted in the work [2]. For this, we consider an enterprise composed of four production units *(U_1, U_2, U_3, U_4)*, each production unit can be included a number of vacant posts *nvj*.

Firstly, we construct an instance as follow:

- The weighted matrix of candidate is randomly generated *n* interval [20 ; 40] :

$$ME = \begin{pmatrix} 40 & 39 & 39 & 38 & 25 & 14 \\ 34 & 29 & 26 & 0 & 0 & 0 \\ 38 & 34 & 23 & 0 & 0 & 0 \\ 39 & 38 & 36 & 30 & 11 & 0 \end{pmatrix}$$

Figure 4: The weight matrix of candidates

- The cost posts matrix is randomly generated between [4000 ; 7000] :

$$cost\_post = \begin{pmatrix} 7277 & 7031 & 6787 & 6555 & 5922 & 5712 \\ 7060 & 5318 & 5210 & 0 & 0 & 0 \\ 4769 & 3971 & 3462 & 0 & 0 & 0 \\ 7502 & 7235 & 6948 & 6171 & 5344 & 0 \end{pmatrix}$$

Figure 5: The posts costs matrix

- The constraint vector of the global cost is generated in the interval [*14000 ; 37000*], then *Cost_vect =(37000; 14000; 23000; 22000)*
- The capacity constraint vector is generated in the interval [*2, 6*], then $C_k = (6; 3; 3; 5)$.

4.2 Synthetic of results

The following main results of our test were obtained on a computer having *Pentium i5 2.5GHz* with *4GB* of *RAM*. The genetic algorithm proposed was programmed by *Matlab language*.

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We have conducted a flip-flop crossover-mutation methods used in our last work [3]. The aim of this experiment is to find out one combination of these two operators in order to generate the best solution and reduce the execution time of GA.

In figure 6, the ratio weight $Rf = \frac{F-F0}{F0}$ obtained by using an initial population size equal to *80* individuals. *F0* represent the fitness value corresponding to optimal solution obtained and *F0* represent the best fitness value corresponding the initial population before the start of the genetic algorithm.

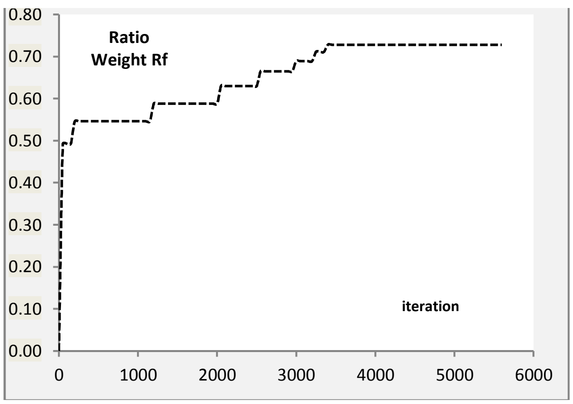

Figure 6: Variation the Weight report depending on number of iterations

The figure 7 shows the results based on one largest problem, the graphical results show that the weight ratioRfis stabilized when our genetic algorithm performed approximately *3500* iterations. This stabilization of Rf indicate the convergence of GA to best solution. When we look this figure, we note that the convergence time for obtaining the best solution in the reasonable time (14 s).

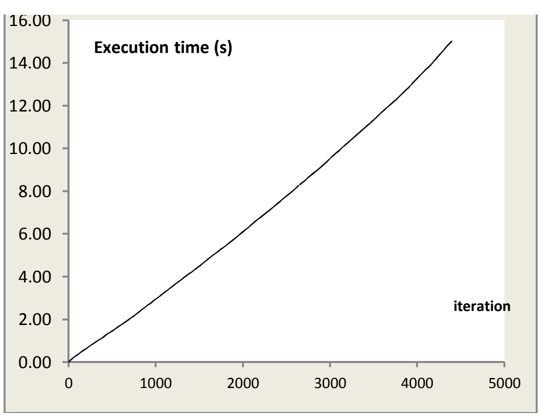

Figure 7: Variation the Execution time depending to maximum number of iterations

The selection of a candidate must also be in reference to a labor collective with reasonable costs, thus productive consequences of this selection should especially and the decision of the new recruit must influence other activity candidates.

The best solution obtained represents the best distribution of the recruited candidates for maximizing overall efficiency. This solution is illustrated in the figure 8.

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

Figure 8: Matrix assignment solution obtained by GA

By applying a genetic algorithm illustrated in the figure 3, the enterprise managers can select highly qualified candidates to assign in order to maximize the global productivity in the production units. Each row *r* of the optimum assignment matrix corresponds to a group of candidates classified in terms of qualification to assign to the r^{th} production unit.

Regarding this matrix result, the value *1* indicates that the candidates are assigned and *0* indicates that the candidate is not assigned. Also, the number of candidates who are assigned to the different production units equal to *11* from among *16* available posts.

These affected candidates are grouped into four categories and can generate the maximum weight. Moreover, the number of affected candidates may be increased if we reduce the individual costs of the posts (*matrix costs*) or we increase the global cost of for each production unit (*vector cost*).

5. CONCLUSION

In this paper, we have described an approach based on multiple knapsack problem and genetic algorithm to optimize the multi-constraints assignment of human resource. This approach can be applied in the recruitment of personnel management. We have formulated this problem as Multiple Knapsacks Problem that is NP-hard problem. The experimental result showed the validity of this approach to assign the qualified candidates capable of influencing positively enterprise by maximizing the profitability and the productivity within the multi sites production enterprise. We have contested the Genetic Algorithms can be used to find the good solution by using the operators of matrix crossover, matrix

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mutation and procedure of flip-flop alternating crossover-mutation.

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