Solving matching Stable Marriage and Salesman Algorithm to find in Employment agents

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Abstract

The important of stable matching theory is to find the suitable of two sets of data, one of these methods called Stable married problem, and its applied to find best match of set based on other one. The proposal of the paper is find best matches of each sets of employers agent for both companies and individual, then compares which the items have closest rank and give the best rank using one of the heuristic algorithm of AI called Traveling Salesman algorithm. The results shows the best suitor matched for both sets during implemented in employment agents.

Keywords: stable marriage, TSP, nearest neighbor

الخلاصة

باستخدام احدى نظريات التطابق المستقر لايجاد افضل تلائم بين عناصر مجموعتين من البيانات، احدى هذه الطرق تسمى نظرية الزواج المستقر والتي تستخدم لايجاد افضل تطابق لعناصر مجموعة نسبة الى مجموعة اخرى. تم في هذه الدراسة إيجاد افضل تطابق في وكالات التوظيف لمجموعتين تتكون من الأشخاص والاخرى من الشركات التي تطلب توظيف اشخاص لديها، وتم تحليل ومقارنة عناصر المجموعتين بايجاد اقرب مرتبة باستخدام مسألة البائع المتجول. وتم التوصل الى نتائج تبين افضل تلائم مطابق لكلا طرفي المجموعتين.

كلمات مفتاحية: الزواج المستقر، البائع المتجول، الجار القرب

Introduction

The job selection procedure in today's global economy can be a daunting task for prospective employees no matter their experience level. It involves a thorough search of newspapers, job websites, human agents, etc, to identify an employment opportunity that is perceived compatible to abilities, expected salary and social needs [2]. When the employee's agent looking for new position or for new employee for any company; the agent start search for suited employee to achieve they company's appropriate position or an appropriate employee. The agents negotiate about the conditions of a contract according to numerous criteria like salary per hour, working hours per week, and social benefits.

The agents in both groups are treated differently. Employees' agents with low-ranking positions on the employers' agents' sequence lists must wait before they receive their first offers, because employers' agents start their simultaneous negotiation processes only with the highest ranked employees' agents [1]. For the ranking of employees' agents, additional scoring functions for age, working experience, professional and additional skills have to be constructed.

One of the previous studies of employee hiring and satisfaction in the types of companies presents the evaluation index system of employee satisfaction in various companies using AHP-Fuzzy methods to analysis on samples of employee in the growing small and micro-businesses [3].

Other study [4] focus on the employee engagement factors extracted from the Happinometer database using a Knowledge Discovery in Database (KDD) technique called decision tree. The extracted rules are filtered and ranked according to its support and accuracy. They've initialed knowledge composes of 17 rules that are further separated into 4 generations for analysis.

Stable Marriage Problem

The Stable Marriage Problem is a combinatorial problem, also useful for Economics and Operations Research. Main theory of this algorithm is to find a stable matching between n set A and n set B, each set has own preferences on every member of the other. A matching is not stable if there exist a set A and a set B not matched with each other, such that each of them strictly prefers the other to partner in the matching. Any instance of this problem has a solution, and it can be computed by the centralized Gale-Shapley algorithm [5].

An instance of the Stable Marriage problem comprises of two sets of size n, such as the men and the women. The whole total of data for an example of size n is actually $O(n^2)$. Each one has a severely ordered preference list covering all the members of the other set, such that a person *p* prefers a person *q* to a person *r* if and only if *q* precedes *r* on *p's* preference list [6].

For such an instance, a matching M is a one-to-one mapping between the two sets such as men and the women. For a pair (m;w) 2 M, we say that m is the partner of w in M, or m = pM(w), and similarly for w. The procedure of stable marriage problem is described in flowchart shown in figure (1).

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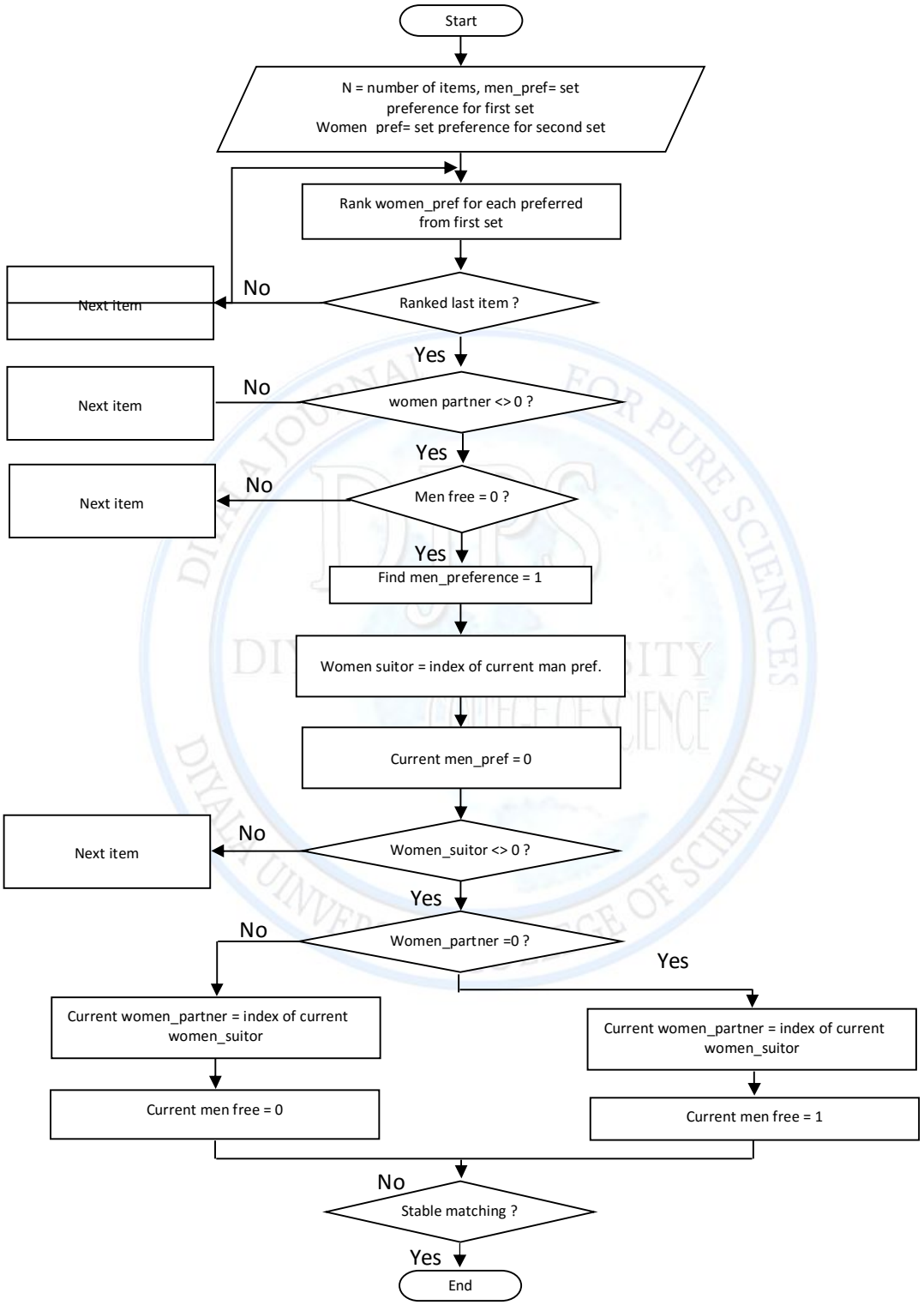

Figure (1) Flowchart describes the process of Stable Married Problem

Salesman algorithm

The most prominent member of the rich set of combinatorial optimization problems is undoubtly the traveling salesman problem (TSP), the task of finding a route through a given set of cities with shortest possible length. The study of this problem has attracted many researchers from different fields, e.g., Mathematics, Operations Research, Physics, Biology, or Artificial Intelligence, and there is a vast amount of literature on it [7].

On the other hand, the TSP is interesting not only from a theoretical point of view. Many practical applications can be modeled as a traveling salesman problem or as variants of it. Therefore, there is a tremendous need for algorithms. The number of cities in practical applications ranges from some dozens up to even millions [8]. Due to this manifold area of applications there also has to be a broad collection of algorithms to treat the various special cases [8].

The TSP can be defined on a complete undirected graph

$$G = (V,E)\ldots\ldots(1)$$

if it is symmetric or on a directed graph

$$G = (V,A)\ldots\ldots(2)$$

if it is asymmetric. The set $V = \{1, \ldots, n\}$ is the vertex set, $E = \{(i, j) : i, j \in V, i < j\}$ is an edge set and $A = \{(i, j) : i, j \in V, i \neq j\}$ is an arc set. A cost matrix $C = c_{ij}$ is defined on E or on A. The cost matrix satisfies the triangle inequality whenever $c_{ij} \leq c_{ik} + c_{kj}$, for all i, j, k. In particular, this is the case of planar problems for which the vertices are points as in equation below

$$P_i = (X_i ,Y_i)\ldots\ldots(3)$$

The objective of a traveling salesman is to move from city to city, visiting each city only once and returning back to the starting city. This is called a tour of the salesman. In mathematical formulation, there is a group of distinct cities $\{C_1,C_2,C_3, \ldots,C_N\}$, and there is given for each

pair of city (C_i,C_j) a distance d (C_i,C_j) . The objective then is to find an ordering π of cities such that the total time for the salesman is minimized. The lowest possible time is termed the optimal time. The objective function is given as:

$$TL = \sum_{i=1}^{N-1} d\left(C_{(i)}, C_{(i+1)}\right) + d\left(C_N, C_1\right) \quad \ldots\ldots (4)$$

This quality is known as the TL (tour length). Two branches of this problem exist, symmetric and asymmetric. A symmetric problem is one where the distance between two cities is identical, given as: $d(C_i,C_j)= d(C_j,C_i)$ for $1 < i, j < N$ and the asymmetric is where the distances are not equal. An asymmetric problem is generally more difficult to solve.

This heuristic for constructing a traveling salesman tour is near at hand. The salesman starts at some city and then visits the city nearest to the starting city. From there he visits the nearest city that was not visited so far, etc., until all cities are visited, and the salesman returns to the start as described below [7], the traveling salesman problem procedure illustrated in figure (2) below.

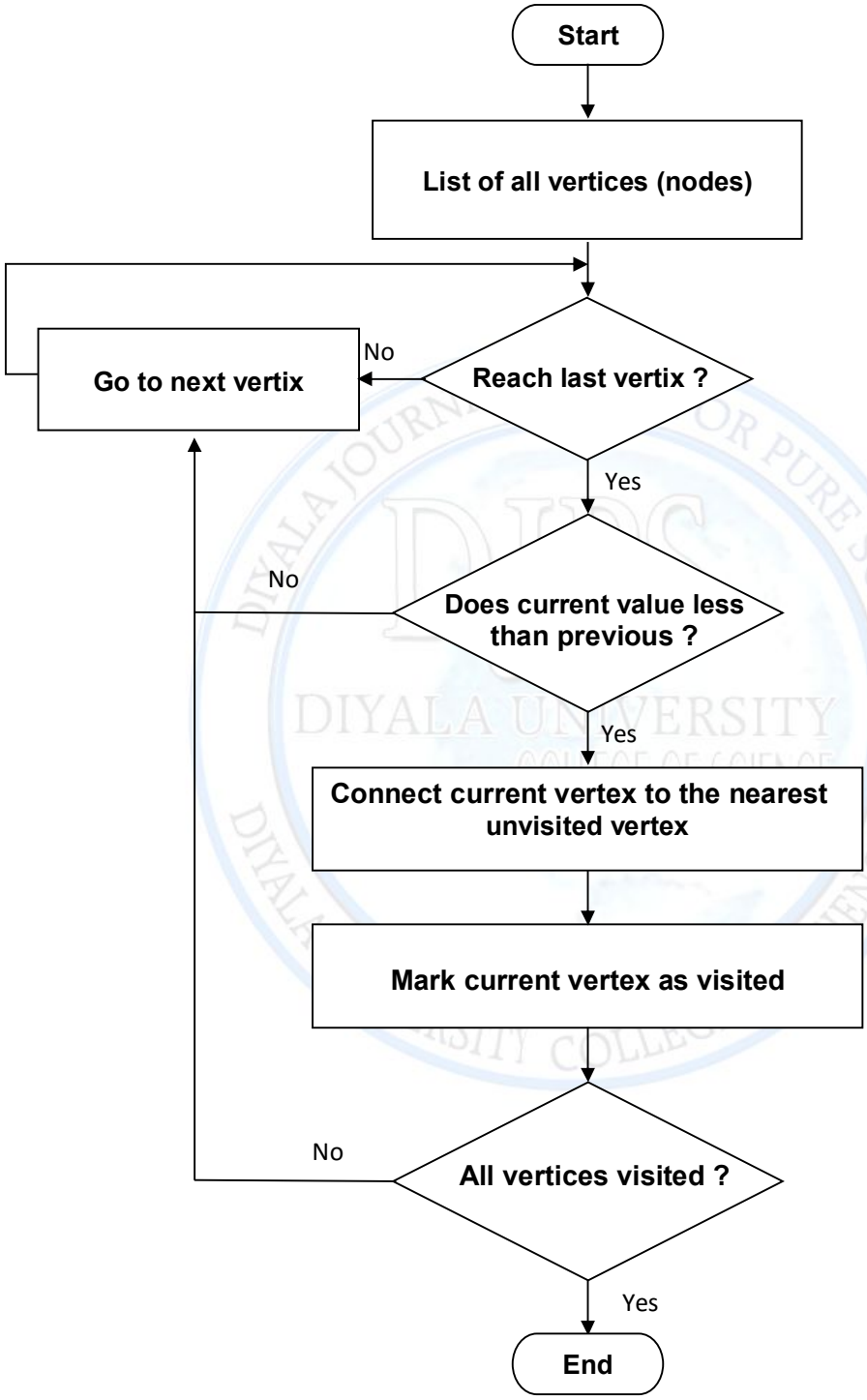

Figure (2) Flowchart illustrates the TSP using nearest neighbor algorithm

Proposed Work

The objective of the proposed work is to find solution for two sets of data; one for each side which determined in employment agencies that have both data belong to companies (set A) need to hire individuals and set of individuals whom need to be hired (set B). Each item in set A has list of preferences of individuals and each item in set B has list of preferences of companies for each individual. The method used in this paper to find the suited pairing for both sets called Stable Marriage Problem. Suppose one of companies (A) whom left unpaired must have check to every individual on company's list. Also, each of these individuals has list of preference companies. Thus, when the algorithm terminates, n individuals have n companies on preferred list. In the end of the algorithm, each company is paired with its own suited individual, which means that all the individuals have suited company as well.

To prove that the output of the algorithm is a stable pairing, first do a sample run-through of the stable marriage algorithm.

A preference lists for each item in set (A) to set (B) has explained in formula below

$$pref_{c \to i_k}(j) = I_k \ldots\ldots (5)$$

Where (c) is preference list of (i) individuals for each (j) company. I_k determined list of (I) individuals. Tables below shows the preferences list for both sets, which are duplicated here for convenience:

Table (1) preference of both sets (companies and individuals)

Company	Individual		
Huda	Ahmed	Basim	Samer
Hikma	Basim	Ahmed	Samer
Baraka	Ahmed	Basim	Samer

Individual	Company		
Ahmed	Hikma	Huda	Baraka
Basim	Huda	Hikma	Baraka
Samer	Huda	Hikma	Baraka

The following tables described the steps of the solution for above sets using stable marriage problem.

First, the company (Huda) has preference individual (Ahmed),

$$pref_{c \to i_1}(1) = Huda \to Ahmed$$

so, in individual table remark (Huda) for (Ahmed) as below.

Table (2) first step, first company select best suitor (individual)

Company	Individual		
Huda	Ahmed	Basim	Samer
Hikma	Basim	Ahmed	Samer
Baraka	Ahmed	Basim	Samer

Individual	Company		
Ahmed	Hikma	Huda	Baraka
Basim	Huda	Hikma	Baraka
Samer	Huda	Hikma	Baraka

Next step, find the paired for second company (Hikma) which is (Basim)

$$pref_{c \to i_2}(2) = Hikma \to Basim$$

and remark it as shown in table below.

Table (3) second company remark the best suitor

Company	Individual		
Huda	Ahmed	Basim	Samer
Hikma	Basim	Ahmed	Samer
Baraka	Ahmed	Basim	Samer

Individual	Company		
Ahmed	Hikma	Huda	Baraka
Basim	Huda	Hikma	Baraka
Samer	Huda	Hikma	Baraka

Now, the third company (Baraka) preferred Ahmed with high rank, but (Ahmed) preferred (Huda) than (Baraka), so, will (Ahmed) paired with (Huda) company, and remark (Ahmed) from (Baraka) list as taken as shown below.

Table (4) eliminate the first individual from the third company

Company	Individual		
Huda	Ahmed	Basim	Samer
Hikma	Basim	Ahmed	Samer
Baraka	Ahmed	Basim	Samer

Individual	Company		
Ahmed	Hikma	Huda	Baraka
Basim	Huda	Hikma	Baraka
Samer	Huda	Hikma	Baraka

Also, (Baraka) company has select next individual (Basim), but (Basim) preferred (Hikma) more than (Baraka),

Table (5) eliminate the second individual from the third company

Company	Individual		
Huda	Ahmed	Basim	Samer
Hikma	Basim	Ahmed	Samer
Baraka	Ahmed	Basim	Samer

Individual	Company		
Ahmed	Hikma	Huda	Baraka
Basim	Huda	Hikma	Baraka
Samer	Huda	Hikma	Baraka

Finally, assign individual (Samer) for (Baraka) company,

$$pref_{c \to i_3}(3) = Baraka \to Samer$$

so, all the items of both sets has paired with suited one as described in table below.

Table (6) third company selects the third individual

Company	Individual		
Huda	Ahmed	Basim	Samer
Hikma	Basim	Ahmed	Samer
Baraka	Ahmed	Basim	Samer

Individual	Company		
Ahmed	Hikma	Huda	Baraka
Basim	Huda	Hikma	Baraka
Samer	Huda	Hikma	Baraka

The stable pairing result from set (A) to set (B) is (Huda → Ahmed, Hikma → Basim, and Baraka → Samer).

In this paper, we've make an enhancement in process of stable marriage algorithm by find stable pairing from second set (set B) and then comparing the results of both sets. Then, find best suited using Traveling Salesman Problem (TSP) as shown in tables below.

First, the individual (Ahmed) has preference company (Hikma), so, in individual table remark (Hikma) for (Ahmed) as below.

Table (7) first step, first individual select best company

Individual	Company		
Ahmed	Hikma	Huda	Baraka
Basim	Huda	Hikma	Baraka
Samer	Huda	Hikma	Baraka

Company	Individual		
Huda	Ahmed	Basim	Samer
Hikma	Basim	Ahmed	Samer
Baraka	Ahmed	Basim	Samer

Next step, find the paired for second individual (Basim) which is (Huda) and remark it as shown in table below.

Table (8) second individual remark the best company

Individual	Company		
Ahmed	Hikma	Huda	Baraka
Basim	Huda	Hikma	Baraka
Samer	Huda	Hikma	Baraka

Company	Individual		
Huda	Ahmed	Basim	Samer
Hikma	Basim	Ahmed	Samer
Baraka	Ahmed	Basim	Samer

Now, the third individual (Samer) preferred Huda with high rank, but (Huda) preferred (Basim) than (Samer), so, (Huda) paired with (Basim), and remark (Huda) from (Samer) list as taken as shown below.

Table (9) third individual eliminate the first company

Individual	Company		
Ahmed	Hikma	Huda	Baraka
Basim	Huda	Hikma	Baraka
Samer	Huda	Hikma	Baraka

Company	Individual		
Huda	Ahmed	Basim	Samer
Hikma	Basim	Ahmed	Samer
Baraka	Ahmed	Basim	Samer

Also, Samer has select next preferred which is (Hikima), but (Hikma) preferred (Ahmed) more than (Samer),

Table (10) third individual eliminate the second company

Individual	Company		
Ahmed	Hikma	Huda	Baraka
Basim	Huda	Hikma	Baraka
Samer	Huda	Hikma	Baraka

Company	Individual		
Huda	Ahmed	Basim	Samer
Hikma	Basim	Ahmed	Samer
Baraka	Ahmed	Basim	Samer

Finally, assign company (Baraka) for individual (so, all the items of both sets has paired with suited one as described in table below.

Table (11) third individual eliminate the second company

Individual	Company		
Ahmed	Hikma	Huda	Baraka
Basim	Huda	Hikma	Baraka
Samer	Huda	Hikma	Baraka

Company	Individual		
Huda	Ahmed	Basim	Samer
Hikma	Basim	Ahmed	Samer
Baraka	Ahmed	Basim	Samer

The stable pairing result from set (B) to set (A) is (Ahmed → Hikma, Basim → Huda, and Samer → Baraka).

As notes, the results from both cases has different. We've using TSP_NN algorithm to find best suited paired from both sets. To solve the TSP as described blow

- find suited pairs with its locations as below

$$c_{i_k} : i_{c_k} = gs(c)$$

Where gs is stable marriage algorithm for each set (c→i and i→c)

- find index of suited pairs

$$L(k) = c_{i_k}, i_{c_k}$$

The L(k) contains suited location of both companies and individuals, and best result for both sets listed in table (12)

Table (12) best stability match for both set (company and individual)

Location	Company → Individual
1	Huda → Ahmed
1	Hikma → Basim
3	Baraka →Samer
	Individual→ Company
1	Ahmed→Hikma
1	Basim→Huda
3	Samer → Baraka

Table (13) has a stable reaches the best matching for both sets. We've design an application to solve large data for each set size with (15),

Table (13) items generated for set (A)

1	F	C	D	L	B	K	O	H	G	A	I	E	N	M	J
2	L	A	C	J	F	E	H	D	B	K	N	G	I	M	O
3	F	A	H	N	E	I	O	C	L	D	J	G	B	M	K
4	B	N	K	O	G	F	J	D	M	A	I	L	C	E	H
5	C	D	J	E	M	L	G	O	I	B	H	N	F	K	A
6	H	M	K	F	E	A	G	O	L	J	D	B	N	I	C
7	I	G	E	N	O	D	F	M	A	B	C	H	K	L	J
8	J	E	M	I	C	G	K	N	F	L	O	H	D	A	B
9	J	F	O	I	N	H	M	B	K	C	L	E	G	A	D
10	K	O	I	G	L	C	D	F	E	N	M	B	J	A	H
11	J	L	C	I	M	N	H	G	B	D	K	O	F	E	A
12	O	A	N	G	H	D	C	K	E	J	F	B	M	L	I
13	H	D	L	C	N	M	G	O	E	F	I	A	B	K	J
14	G	K	J	B	F	M	A	H	E	D	C	O	N	L	I
15	G	C	O	K	A	B	J	I	F	M	D	L	N	E	H

Table (14) items generated for set (B)

A	6	2	13	5	4	1	8	9	14	12	11	7	3	10	15
B	8	6	5	11	12	13	7	9	1	2	15	14	4	10	3
C	2	11	15	9	1	7	14	5	12	4	8	10	3	6	13
D	3	11	1	2	5	14	6	13	4	9	8	15	12	10	7
E	14	2	5	10	6	13	7	9	11	12	3	15	1	8	4
F	9	3	12	6	5	14	15	4	10	2	8	1	11	7	13
G	3	8	5	1	15	6	14	9	7	10	12	13	2	11	4
H	2	8	7	1	14	4	9	13	15	11	6	5	12	3	10
I	3	5	8	7	1	6	12	14	10	9	11	13	2	15	4
J	9	8	6	13	4	2	15	10	3	14	5	11	1	12	7
K	4	6	8	7	1	15	11	14	12	5	2	9	13	3	10
L	9	13	10	3	5	1	4	6	12	7	11	14	2	15	8
M	1	3	7	14	13	12	2	9	5	4	8	11	6	10	15
N	7	13	2	12	1	10	3	8	14	11	6	5	4	15	9
O	3	13	11	5	6	4	8	15	14	9	10	2	12	1	7

The given a set of (n=15) companies and a set of (n=15) individuals, each company make a list of the individual is willing to hired. Then, run stable marriage algorithm for each set. The two set are stable because instability requires both participants to be happier. But matching results are different as described in table (15) below.

Table (15) matching result

Set (A)		Set (B)	
Company	Individual	Individual	Company
1	B	A	4
2	D	B	3
3	A	C	6
4	E	D	11
5	H	E	5
6	C	F	1
7	O	G	14
8	M	H	9
9	G	I	10
10	I	J	15
11	N	K	2
12	K	L	12
13	F	M	8
14	L	N	13
15	J	O	7

The algorithm converges in a single round on the suitor-optimal solution because each reviewer receives exactly one hired, and therefore selects that hired as its best choice, ensuring that each suitor has an accepted offer, ending the match.

As notes from the table above, company (1) has paired with individual (B) when executes the algorithm from set (A) to set (B), whereas individual (B) has been paired with company (4) when executes the algorithm from set (B) to set (A).

In this problem, we've proposed solution using nearest neighbor algorithm on TSP. The procedure starts by finding which is closest location from both sets for each suited item such as individual (B) is suited for company (1) and rank is (5) whereas the company (1) suited for individual (F) ranked (11), so, the minimum rank is (5) and be select as best result from set (A). Table (16) below contains the result of best suited paired from both sets.

Table (16) best result of proposal work

Sr.	Suited pair	Paired
1	'suited from set (A)'	B
2	'suited from set (B)'	3
3	'suited from set (B)'	6
4	'suited from set (A)'	E
5	'suited from set (B)'	5
6	'suited from set (A)'	C
7	'suit from both sets (A and B)'	O
8	'suited from set (B)'	9
9	'suited from set (A)'	G
10	'suited from set (A)'	I
11	'suited from set (B)'	2
12	'suited from set (B)'	12
13	'suited from set (B)'	8
14	'suited from set (A)'	L
15	'suited from set (B)'	7

Conclusion

Humans are widely regarded as the most valuable resources in modern companies and organizations. Though, larger number of humans employed may not always contribute to company's success. There are evidences that smaller companies could outperform the larger ones. In fact, one of the keys to the success is the employee engagement. The higher engagement will lead to the better organization performance, but the side effects could result in more unhappy employees. Our study focus on enhancement of the solution of the Stable marriage algorithm by satisfying both items of each set by find the closest rank from both of set using TSP by method nearest neighbor. We've have designed a program to solve large data using Matlab v.13.

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