A Matching Mechanism for Homecare Service based on Patient's and Caregiver's Criteria

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***Abstract*—With advancement in medical technology and increasing average life expectancy, developed countries have gradually entered the aged society, making the health care for the elderly population a serious topic. In Taiwan, among the long-term care (LTC) service items, home care service is the primary concern. According to the experience of advanced countries, manpower shortage of home care service is the problem to be tackled. Therefore, LTC should focus on maximizing the efficiency in the resource allocation of limited manpower. In the past, home care attendants were dispatched by institutions to patients' home. With the prevalence of mobile network and smartphones, the business model of digital economy is affecting traditional industries and creating a new "platform economy" model which allows direct transaction among suppliers and clients, thereby creating values for all sectors in this process. Hence, this study proposes a matching calculation mechanism, including matching algorithm, home care preference menu and mobile application so that caregivers and elderly can find the most suitable match based on their needs. The proposed matching system can allocate human resources properly and enhance caregivers' willingness to work. Moreover, it can help elderly and families to more quickly and accurately find the appropriate caregivers, reduce their burdens, and allow the elderly to achieve home-based ageing.**

***Index Terms*—long-term care, home care service, platform economy, matching algorithm**

I. Introduction

Since Taiwan entered into an aging society in 1993, the elderly proportion aged 65 and above has been increasing, and is expected to exceed 14% by 2018, making Taiwan an aged society. This number will exceed 20% in 2025 by which time Taiwan will become a super-aged society, and will jump to 41.6% by 2060. Moreover, the dependency ratio is estimated to be 34.7% in 2012, reaching the bottom, before gradually increasing to 97.1% by 2060. In terms of the dependency burden of the elderly population on young people, approximately 6.7 young people support 1 elderly in 2012, but in 2060 approximately 1.3 young people need to support 1 elderly [1]. As seen, the care burden of Taiwanese will become heavier and it is a topic worth studying.

As the population aging rate and the average life expectancy increase, so will the number of the disabled elderly people needing care. A study found that the population in need of long-term care (LTC) in Taiwan was 245,551 in 2007, and it will soar to 398,130 by 2020 [2]. With the growing need of LTC, the demand for home care attendant is a problem to be concerned.

Among the demands for LTC services in Taiwan, home care service is the most needed service item [3]. According to the statistics from the Ministry of the Interior, between 2003 and 2011, the number of people using home care service increased from 14,415 to 33,193, the person time using home care service increased from 842,699 to 4,749,949, and the hours of services increased from 2,084,187 to 9,002,335 respectively[3]. This suggests that the use of home care service is on the rise year by year.

LTC home service include domestic help, daily life care and physical care services, such as cleaning, accompanying to doctor's visit, bathing, turning over and patting back as well as limb activities. The home-based care service allows those needing service to live in their original residence, thus fulfilling ageing in place.

Shortage of home caregivers has been a common problem faced by all advanced countries, and Taiwan is no exception. Moreover, many caregivers have low intention to work in the home care field. A study on the employment intention of care service trainees found that only 35.5% of them would choose to work in the LTC field, mostly in hospitals (34.2%), followed by seniors' home (33.2%), LTC institutions (30.8%) and day care institutions (1.7%). In other words, only 10% of those trainees would engage in home care service [4]. As it is difficult to retain home caregivers, maximizing the resource allocation of limited manpower and encourage more people to join the labor force is important to achieve the highest efficiency.

This study designs a matching service platform for home caregivers and elderly to find the most appropriate candidates. The matching calculation is based on their respective requirements. This platform can properly

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allocate human resources, enhance the employment intention of caregivers, help families and patients to more quickly and accurately find the right home caregivers, simplify the home service application process, allowing elderly to enjoy quality home care service and achieve home-based care.

II. Literature Review

A. Home Care Service in Taiwan

LTC is defined as "providing continuous medical and social services to help people with chronic health problems so that they are able to live their everyday life [5]". The service items include general home care service, day care, shuttle service, etc. Specifically, home care services can be divided into home medical services, home nursing care, personal care and family services. The first two services are provided by professional medical staff, whereas the latter two services are offered by caregivers.

Home caregivers refer to people who are dispatched by the home care service providers to the patients' home. They usually provide the following two service items: 1) housework and daily life care services, including washing and repair of clothes, cleaning the living space, housework and clerical services, preparing meals, accompanying clients to grocery shopping or doctor's visit, etc.; 2) physical care services, including providing help in bathing, putting on clothes, oral cleaning, eating and medication, turning over, patting back, limb activities, going to and getting out of bed, accompanying to take a walk and exercise, assisting in the use of daily life aids, etc. [6].

The current shortage of home caregivers has become a common problem faced by many advanced countries. Home caregivers not only need professional training, but also face challenges and pressure at work. Sometimes they are not even being respected, thus lowering their intention to work as home caregivers.

OECD countries have proposed the concept of "improving the value of services" following the principle of expanding human resources of home caregivers, in order to fully utilize the resources and increase the quality output of services. Based on the two strategies of utilizing existing human resources and introducing science and technology [7], they provide a sound assistance platform, allowing more patients in need of help to receive suitable services and reach high care effectiveness.

B. Platform Economy-Based Matching Mechanism

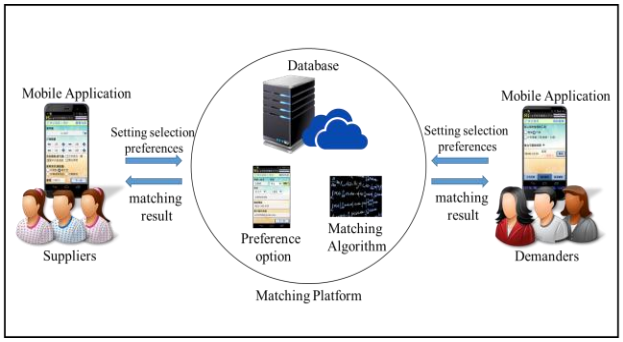


Figure 1. System concept structure.

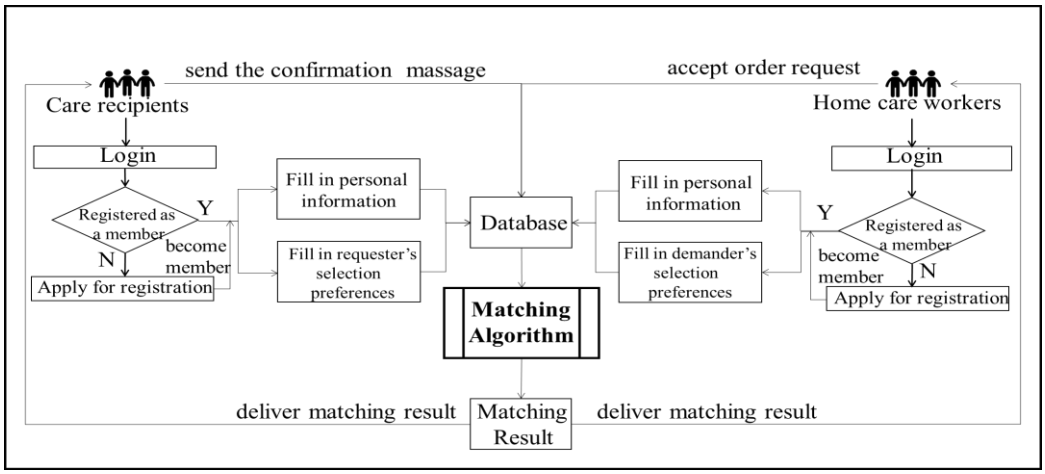


Figure 2. System operational flowchart.

The development of platform economy of data technology has changed the traditional business model. Without physical assets, platform economy with a new economic model creates new service models, bringing new business opportunities.

Platform economy is driven by digital technology and big data, and is supported by transaction platform. It has integrated consumers and service providers to become highly collaborative platform economy. The matching platform allows specific demanders and specific suppliers to interact and trade (communicate) through understanding and screening their respective data [8].

The primary purpose of the platform is to link the products or services of both sides. As shown in Fig. 1, the bridging and matching of the platform enable "resources" to be effectively shared, which is the "shared economy". It also allows matching users to increase product, service or social currency transactions (exchanges), and must integrate "people", "organization" and "resources" to create value for all participants. The central core of the

platform is "technology" which is surrounded by the above three elements to establish an interactive ecological network [8]. As shown in Fig. 2, this study constructs a "technology" platform, builds a basic structure to connect suppliers (home caregivers) and demanders, and proposes complete platform use and interaction rules. By means of matching calculation, it quickly and effectively matches the connected specific groups.

The proposed matching platform can match the caregivers and patients, allow the caregivers to select clients based on their capacity and the patients to receive quality home care service.

III. Research Method and Analysis

A. System Requirements Analysis and System Context Diagram

To find caregivers, the clients need to contact the home care service company and submit applications; the company dispatches the caregivers. The process is time-consuming and cumbersome, and the services may not meet individual needs. Moreover, the caregivers are chosen by the company, and the client does not have any choice during the process. In case the caregiver is inappropriate, it is troublesome for the client.

This study develops a matching calculation mechanism, including matching algorithm, home care preference menu and mobile application so that home caregivers and clients can find the most appropriate match based on their needs. Take the home cleaning service as an example, the matching module is the main calculation basis. The home caregivers and clients can input their requirements on an App. The clients could screen the caregivers that meet their needs; the caregivers could evaluate the service items and salary stated in the job. The automatic matching calculation helps both sides to quickly find the most suitable candidates.

B. Matching Algorithm and Operating Process

Gale-Shapley (GS) algorithm, also known as the deferred-recognition algorithm, was first proposed by American mathematicians David Gale and Lloyd Shapley in 1962 for dating match. The matching results produced by GS algorithm have been proven stable.

Many subsequent studies have been conducted on the matching problem of two parties in various fields. Roth [9] used the GS algorithm to design a matching mechanism for high schools in New York that paired students and schools. Compared with the previous results, only 10% of students were allocated to the schools not preferred by the students in this algorithm. In 1998, Roth et al. [10] used the GS algorithm to allocate interns and hospitals in the U.S., in order to improve the country's physician matching programs and satisfy a vast range of new needs. Lagesse [11], based on the GS algorithm, analyzed the allocation of the enterprises' internal staff and positions, which could also make the best use of the enterprises' internal human resources.

Taking dating match as an example, the operating process of GS algorithm is as follows: (1) A matching X is a set, in the number pair (A, a), A means men and a means women. i.e., X={(M,W)|M is man, W is woman}, and each man can be paired with one woman only and each woman with one man only; (2) in a match between a man M and a woman W, M prefers W over his current favored partner and W prefers M over her current favored partner, this is called an unstable match. Assuming that men are M = {M_1, M_2, M_3, M_4}, and women are W = {W_1, W_2, W_3, W_4}.

Step 1: Each man lists his preferences in women and each woman lists her preferences in men, as shown in Table I and Table II.

TABLE I. Preference Ordering of Men

M_1	W_1	W_2	W_3	W_4
M_2	W_2	W_4	W_1	W_3
M_3	W_2	W_1	W_3	W_4
M_4	W_3	W_2	W_4	W_1

(For M_1, the degree of preference is W_1> W_2> W_3> W_4)

TABLE II. Preference Ordering of Women

W_1	M_4	M_3	M_1	M_2
W_2	M_2	M_1	M_4	M_3
W_3	M_4	M_3	M_2	M_1
W_4	M_3	M_2	M_1	M_4

(For W_1, the degree of preference is M_4> M_3> M_1> M_2)

Step 2: Each man proposes to the woman he prefers most, and if a woman is proposed to by a man, then the matching stops. When a woman is proposed to by more than two men, this woman chooses the more-preferred man. Next, the rejected man proposes to his second preferred woman, and the woman could choose a more preferred man and reject the previous partner. This process ends until each woman has accepted one man.

Step 3: The matching process is as follows: the men first propose to the women they most prefer: $M_1 \rightarrow W_1$; $M_2 \rightarrow W_2$; $M_3 \rightarrow W_2$; $M_4 \rightarrow W_3$. When M_2 and M_3 propose to W_2 at the same time, if W_2 chooses M_2, M_3 is forced to propose to his second preferred woman W_1. Then M_2 finds that in the first round of proposal, M1 has proposed to W_1. According to the definition of stable matching, a woman can choose the partner she prefers to this time and rejects her current partner. Therefore, W_1 can choose between M_1 and M_3. As she prefers M_3 over M_1, she thus rejects M_1 and chooses M_3. After M_1 is rejected and forced to propose to his second preferred woman W_2, and finds that W_2 has just chosen M_2. Then W_2 can choose between M_2 and M_1, and she still prefers M_2 over M_1, so M_1 must propose to his third preferred woman W_3. Then M_1 finds that similarly, M_4 has proposed to W_3, so W_3 can choose between M4 and M_1 and she still chooses M_4 over M_1. As a result, M_1 must propose to his fourth preferred woman W_4, and finds W_4 has not been proposed to and matched, so M_1 and W_4 are successfully matched.

The final stable matching results are {(M_1, W_4), (M_2, W_2), (M_3, W_1), (M_4, W_3)}. It is noted that after men make n proposals, they face less-preferred partners, while women can find more preferred men. The same applies to women after making n proposals. It is concluded that making more proposals can yield stable matching result, but the results may differ from initial choices.

According to the GS algorithm, the matching of a single item can be applied to various areas. Nevertheless, for home care services, there are multiple items with multi-dimensional preference, so it is necessary to modify the algorithm, in order to match the most suitable candidates. The matching process will be described in the following section.

C. Matching Items and Matching Calculation

Given that only the single item matching can be performed by the GS algorithm and multi-dimensional item matching cannot be carried out, this study proposes an improved matching algorithm, which contains two steps. *Step 1:* Select from the preferred menu and key fields. The caregivers and clients can freely choose their preferences. *Step 2:* Conduct matching calculation. The calculation is performed respectively to find the most appropriate candidate, and match the caregivers to the client. The details are described as follows:

Step 1: Select from the preferred menu and key fields.

After referring to the service items offered by various home care service companies in Taiwan, the key matching fields are defined as: gender, region (distance), service date and time interval (time), floor area to be covered, and salary. These five items are filled out by both caregivers and clients.

Step 2: Conduct matching calculation.

An example of the matching calculation is given based on the five key matching fields.

As shown in Table III, assuming that the clients are P = {P_1, P_2, P_3, P_4}, and they are placed in an order based on their respective degree of preference.

TABLE III. PREFERENCE ORDERING OF THE CLIENTS

Care recipients	Preference sorting			
P_1	gender	fee	distance	time
P_2	distance	time	fee	gender
P_3	fee	gender	time	distance
P_4	fee	distance	time	gender

(For P_1, the preference ordering is gender> salary > distance> time)

As shown in Table IV, assuming that the home caregivers are C = {C_1, C_2, C_3, C_4}, and they are placed in an order based on their respective degree of preference.

TABLE IV. PREFERENCE ORDERING OF HOME CAREGIVERS

Home care workers	Preference sorting			
C_1	distance	fee	time	gender
C_2	gender	fee	time	distance
C_3	fee	distance	time	gender
C_4	distance	gender	fee	time

(For C_1, the preference ordering is distance> salary> time> gender)

For client **P_1**, according to Table V, the preferences of **P_1** toward **C_2, C_3** and **C_4** are determined and the basic conditions of home caregivers (the parameters provided by the caregivers) are compared. When these basic conditions meet the preferences of **P_1**, the rating of A is given; B is given if they differ. Therefore, in case of 4A (AAAA), this home care worker is the most suitable candidate. The sequences are 3A1B (AAAB, AABA, ABAA, BAAA)>2A2B (AABB, ABAB, BBAA, BABA, BAAB, ABBA)>1A3B (ABBB, BABB, BBAB, BBBA)>4B (BBBB), and 4B is the most inappropriate candidate.

TABLE V. COMPARISON OF P1'S MATCHING CALCULATION

	Preference sorting				
	P_1	X_1	X_3	X_4	X_2
Basic conditions	**C_1**	C^1X_1	C^1X_3	C^1X_4	C^1X_2
	C_2	C^2X_1	C^2X_3	C^2X_4	C^2X_2
	C_3	C^3X_1	C^3X_3	C^3X_4	C^3X_2
	C_4	C^4X_1	C^4X_3	C^4X_4	C^4X_2

(**P_1**'s preference order is $X_1 > X_3 > X_4 > X_2$, X_1 = gender, X_3 = salary, X_4 = distance, X_2 = time)

Next, the table is divided to give a more detailed description of how to calculate the matching scores of the 4 home caregivers (**C_1, C_2, C_3, C_4**) for **P_1**.

TABLE VI. MATCHING CALCULATION OF P1 AND C1

P_1 and **C_1** matching score				
P_1 preference sorting	X_1	X_3	X_4	X_2
C_1 basic conditions	C^1X_1	C^1X_3	C^1X_4	C^1X_2
score	**B**	**A**	**B**	**B**

As shown in Table VI, **P_1**'s first preference is X_1 (i.e., gender), and is compared with **C_1**'s gender (C^1X_1). If the condition is met, the rating is A, or else, the rating is B. Here, assuming that $X_1 \neq C^1X_1$, B score is obtained; $X_3 = C^1X_3$, A score is obtained, $X_4 \neq C^1X_4$, B score is obtained; $X_2 \neq C^1X_2$, B score is obtained; the final matching degree of **C_1** with **P_1** is 1A3B (BABB).

TABLE VII. MATCHING CALCULATION OF P1 AND C2

P_1 and **C_2** matching score				
P_1 preference sorting	X_1	X_3	X_4	X_2
C_2 basic conditions	C^2X_1	C^2X_3	C^2X_4	C^2X_2
score	**A**	**A**	**B**	**B**

As shown in Table VII, **P_1**'s first preference is X_1 (i.e., gender), and is with **C_2**'s basic condition of gender (C^2X_1). If the condition is met, the rating is A, or else, the rating is B. Similarly, X_3 (salary), X_4 (distance) and X_2 (time) are compared with **C_2**'s basic conditions. Here, assuming that

$X_1 = C^2X_1$, A score is obtained; $X_3 = C^2X_3$, A score is obtained; $X_4 \neq C^2X_4$, B score is obtained, $X_2 \neq C^2X_2$, B score is obtained; the final matching degree of $\mathbf{C_2}$ with $\mathbf{P_1}$ is 2A2B (AABB).

TABLE VIII. MATCHING CALCULATION OF P1 AND C3

$\mathbf{P_1}$ and $\mathbf{C_3}$ matching score				
P_1 preference sorting	X_1	X_3	X_4	X_2
C_3 basic conditions	C^3X_1	C^3X_3	C^3X_4	C^3X_2
score	**B**	**B**	**B**	**B**

As shown in Table VIII, $\mathbf{P_1}$'s first preference is X_1 (i.e., gender), and is compared with $\mathbf{C_3}$'s basic condition of gender (C^3X_1). If the condition is met, the rating is A, or else, the rating is B. Similarly, X_3 (salary), X_4 (distance) and X_2 (time) are compared with $\mathbf{C_3}$'s basic conditions. Here, assuming that $\mathbf{P_1}$ does not meet all basic conditions of $\mathbf{C_3}$. In other words, $X_1 \neq C^3X_1$, B score is obtained; $X_3 \neq C^3X_3$, B score is obtained, $X_4 \neq C^3X_4$, B score is obtained; $X_2 \neq C^3X_2$, B score is obtained; the final matching degree of $\mathbf{C_3}$ with $\mathbf{P_1}$ is 4B (BBBB).

TABLE IX. MATCHING CALCULATION OF P1 AND C4

$\mathbf{P_1}$ and $\mathbf{C_4}$ matching score				
P_1 preference sorting	X_1	X_3	X_4	X_2
C_4 basic conditions	C^4X_1	C^4X_3	C^4X_4	C^4X_2
score	**B**	**B**	**B**	**A**

As shown in Table IX, $\mathbf{P_1}$'s first preference is X_1 (i.e., gender), and is compared with $\mathbf{C_4}$'s basic condition of gender (C^4X_1). If the condition is met, the rating is A, or else, the rating is B. Similarly, X_3 (salary), X_4 (distance) and X_2 (time) are compared with $\mathbf{C_4}$'s basic conditions. Here, assuming that $X_1 \neq C^4X_1$, B score is obtained; $X_3 \neq C^4X_3$, B score is obtained, $X_4 \neq C^4X_4$, B score is obtained; $X_2 = C^4X_2$, A score is obtained; the final matching degree of $\mathbf{C_4}$ with $\mathbf{P_1}$ is 1A3B (BBBA).

As shown in Tables VI to IX, the matching scores of the 4 home caregivers $\mathbf{C_1}$, $\mathbf{C_2}$, $\mathbf{C_3}$ and $\mathbf{C_4}$ for $\mathbf{P_1}$ are $\mathbf{C_1}$: 1A3B (BABB), $\mathbf{C_2}$: 2A2B (AABB), $\mathbf{C_3}$: 4B (BBBB) and $\mathbf{C_4}$: 1A3B (BBBA). As the scores of $\mathbf{C_1}$ and $\mathbf{C_4}$ are the same, the order of their rating is compared. $\mathbf{C_1}$ is BABB, while $\mathbf{C_4}$ is BBBA. In the matching calculation, the preference order of A which is ranked higher and is matched more quickly. Therefore, rating A of $\mathbf{C_1}$ is ranked second, and that of $\mathbf{C_4}$ is ranked fourth. Hence, the matching degree of $\mathbf{C_1}$ with $\mathbf{P_1}$ is greater than that of $\mathbf{C_4}$ with $\mathbf{P_1}$.

The matching degree of the home caregivers $\mathbf{C_1}$, $\mathbf{C_2}$, $\mathbf{C_3}$ and $\mathbf{C_4}$ with $\mathbf{P_1}$ is $\mathbf{C_2}$> $\mathbf{C_1}$> $\mathbf{C_4}$> $\mathbf{C_3}$, so $\mathbf{C_2}$ is the most suitable candidate. According to the matching calculation, the same calculation is carried out for clients $\mathbf{P_2}$, $\mathbf{P_3}$ and $\mathbf{P_4}$ against caregivers $\mathbf{C_1}$, $\mathbf{C_2}$, $\mathbf{C_3}$ and $\mathbf{C_4}$. The preferences of home caregivers $\mathbf{C_1}$, $\mathbf{C_2}$, $\mathbf{C_3}$ and $\mathbf{C_4}$ and the basic conditions set by clients $\mathbf{P_1}$, $\mathbf{P_2}$, $\mathbf{P_3}$ and $\mathbf{P_4}$ can be matched (see Table X). The above matching calculation can determine the most suitable candidates for both sides.

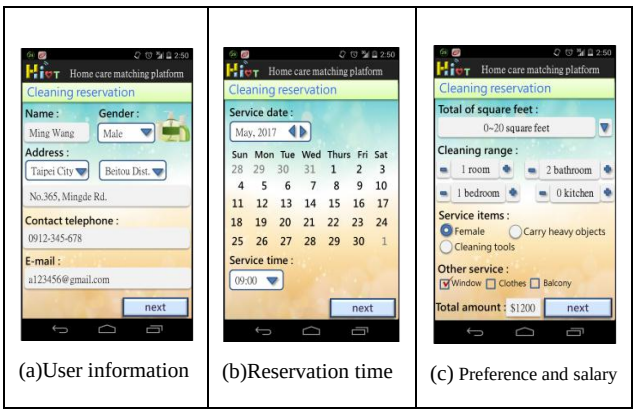
TABLE X. COMPARISON OF C1'S MATCHING CALCULATION

		Preference sorting			
	C_1	X_4	X_1	X_3	X_2
Basic conditions	**P_1**	P^1X_4	P^1X_1	P^1X_3	P^1X_2
	P_2	P^2X_4	P^2X_1	P^2X_3	P^2X_2
	P_3	P^3X_4	P^3X_1	P^3X_3	P^3X_2
	P_4	P^4X_4	P^4X_1	P^4X_3	P^4X_2

($\mathbf{C_1}$'s preference order is $X_4 > X_1 > X_3 > X_2$, X_4 = distance, X_1 = salary, X_3 = time, and X_2 = gender)

IV. EXAMPLES AND DISCUSSIONS OF PLATFORM USAGE

As shown in Fig. 3, an application platform is developed with Android for the caregivers and clients to fill out the applications and perform matching on smartphones.



(a)User information (b)Reservation time (c) Preference and salary

Figure 3. Home cleaning dispatch preference selection APP.

The App is on the cloud platform that allows the users to select their preferences. As shown in Fig. 3-a, users first fill out the basic information, where gender and regions are used for matching calculation. Fig. 3-b shows the appointed service date and time intervals, where home caregivers and clients can indicate their desired service time intervals for matching calculation. Fig. 3-c shows the users' preference and expected salary. Then, the users select their priority of preferences, namely gender, region (distance), service date and time intervals (time), and salary. The degree of preference is used for matching calculation, and selects the optimal matching combination.

V. CONCLUSION

This study developed a home care service matching platform. Using home cleaning services as an example, this study demonstrated the matching of home caregivers and clients to effectively find the suitable candidate based on the individual needs. It can simplify the time-consuming application process in the past, significantly relieving families' burden, and enhance the employment intention of home caregivers. The patients can receive high quality home care services and achieve aging at home.

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