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Using information and mobile technology improved elderly home care services

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KEYWORDS
Elderly home care;
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Usability

Abstract
Background: Many international studies recognized that home care services for elderly can reduce a health system's financial burden while maintaining high quality standards of patient care. Nevertheless, published research also reports that first-line care or in-charge nurses often face many challenges while delivering the home care services. To deal with the challenges, researchers have suggested applying information and mobile communication technology (IMCT) to enhance the utilization of elderly home care services.
Methods: We used a Service Oriented Architecture (SOA) to design the system structure and applied an IMCT to develop a mobile roaming sessions of the home care management system to help first-line nurses efficiently deliver care services while implementing functionality. The system includes three main modules: work scheduling, care service, and patient management. The work scheduling module used genetic algorithms to automatically generate monthly work schedules for nurses. Finally, we interviewed several users to understand the system usability.
Results: We conducted a user experience interview to document and analyze the feasibility and efficiency of the system. The results showed that users found the system very useful in improving the home care services. Particularly, the care scheduling, care management, tour planning, and service logging functions are the most useful features of IMCT tools for improving the home care services. However, the small mobile phone screen and function integrations were main constraints in the system usability.
Conclusions: We applied IMCT to develop a mobile roaming sessions of home care management system to help first-line nurses efficiently deliver care service. The SOA approach

Abbreviations: API, Application Programming Interface; CRM, Customer Relationship Management; GA, Genetic Algorithm; GCA, Genetic Clustering Algorithm; GMCA, Genetic Medoid Clustering Algorithm; IMCT, Information and Mobile Communication Technology; IT, Information Technology; MTSP, Multiple Travelling Salesman Problem; RARwGA, Random Assorted Recombination Genetic Algorithm; SED, Sum of Euclidean Distance; SOA, Service Oriented Architecture

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successfully allowed us to combine existing information applications in a hospital to the *ad hoc* reporting in a home care management system. The system cost effectively improved elderly care services for small- to medium-sized home care centers.

Background

According to the United Nations Population Fund (UNFPA) report, the number of older persons (over 60 years of age) had increased to over 810 million by 2013. It is projected to reach two billion, with one in five persons in the world aged over 60 years by 2050 [32]. Population ageing poses a significant challenge for the health care systems in many countries in the world. For instance, in Taiwan, people over 65 years old accounted for 11.2% of the entire population and consume around 30.7% of government health care expenditures [21]. In Canada, older Canadians (>65 years old) comprise 14% of the population and this age class spends ~45% of government health care budgets [9].

Home care generally refers to supportive care provided in the patient's residential home by licensed healthcare professionals. Many publications recognized that the onsite health care services for elderly can reduce financial burden while preserving care quality [13,18,24,4]. For example, Sullivan [31] compared costs of providing treatment at home to alternative settings including hospitals and nursing homes in BC, Canada. The study found that home care costs were significantly less compared with similar nursing facilities. In fact, the average savings ranged from 25% to 60%. Additionally, Paul et al. [23] study also showed that outpatient (home) nursing care was more cost effective than inpatient nursing care. In regards to care quality, Shyu and Lee [26] found that providing home care was more suitable for patients that were seriously ill rather than in-house nursing-home care for patients not seriously ill with any prescribed services after discharge from the hospital. Furthermore, in many Asian countries, such as Taiwan, most elderly people desire to stay in their homes with family as long as possible despite a potential need for hospital services.

Many studies report that nurses often face many challenges in their service delivery with a lack of continuous professional training, scarcity of technology investments to support complex care needs, and increasing time pressure and client demands while deliver the home care services [27,6,8,10]. These factors affect the provision of care quality negatively [3,12,18,34].

In Taiwan, home healthcare services are reimbursed by the National Health Insurance (NHI) program. Currently, most of the professional home healthcare were provided by community home nursing care institutions [7]. Patients need to fulfill three criteria to receive home healthcare services. The criteria are: (1) limited ability of self-care, (2) definite medical or nursing care needs, and (3) chronic conditions requiring long-term nursing care. Registered nurses need to complete additional training courses to become practice home healthcare nurses [7]. Similar to many other home healthcare workers in the world, home healthcare nurses in Taiwan faced high work stress which may affect service quality. Six factors lead to the stress: insufficient ability, stressful reactions, heavy workload, trouble in care work, poor management, and working time problems [14].

Many published literature suggest that information and mobile communication technology (IMCT) can improve elderly home care services [11,17,19,28,30]. Especially, when it comes to information exchange, knowledge sharing and documentation at the point-of-care the IMCT can be an enabling technique [33]. Using IMCT, first-line nurses can provide timely access related to care knowledge for patients with challenging illnesses or diseases.

However, many small- to medium-sized home care centers have limited funds to construct comprehensive information infrastructure and invest in advanced IT facilities to support care services. Instead, they tend to integrate existing hardware and software to develop a multi-system platform to perform the tasks [15]. Similar to many other home care centers, first-line nurses' workload can dramatically increases due to increasing service demands, and thus affecting the quality of care services.

The objective of this study is to develop an efficient and cost effective mobile session roaming home care management system to improve elderly care services for small- to medium-sized home care centers with a limited budget. First, interviews will be conducted with end users to understand user requirements. Next, a prototype will be designed and implemented to test the utilization of the system. Finally, we will conduct a user experience interview to assess usability and workflow feasibility of the system.

Methods

User requirement analysis

In this study we used a Taiwan medium-sized home care centre (i.e. X-hospital, which will remain anonymous in this study) as a case study. In order to provide the best solution to the home care delivery issues of X-hospital, we formed a focus group and conducted a open question interview with the manager, the computer center director, the head nurse, and two home care nurses to understand the current key service issues for the hospital. Also, we reviewed several existing commercial products to understand if they can be useful for the care center.

Based on the interview results, we drew the functional requirements as described in Section 2.2. Furthermore, the study found that the off-the-shelf products did not fit the care center's requirements. Those software are either too expensive or do not provide all required functionalities (e.g. without Chinese interface).

The system functions

The mobile roving home care management system includes three main modules: (1) Work scheduling, (2) Care service, and (3) patient management as shown in Figure 1.

(1) Work scheduling module supports the following functions:
   a) Care events generation
      This function access the database to extract patient demographic data, requested service items, service period and home location to generate care events.
   b) Patient clustering
      The main task is to cluster patients based on their home locations and service items. Then, the system uses a genetic algorithm (GA) to fit a nurse to a cluster of patients.
   c) Work scheduling
      After patient clustering, the work scheduling function uses a genetic algorithm (GA) to automatically generate a monthly working schedule. The head nurse can fine tune the schedule to fit a special/emergent case.

(2) Care service module provides following functions:
   a) Care tour planning
      This function uses Google Map API to provide a nurse the most time saving route to reach a patient's home.
   b) Care management
      This function provides an interface to let front-line nurses manage and record on-site care data. Nurses can use mobile devices (e.g. laptop computer or tablets) to access care information through this interface. The information includes special care requirements for the patient, family notes and expectations, and particular precautions etc. When nurses complete the home care service, they also use the interface to upload the patient's current condition to the hospital/care center database.
   c) Service logging
      First-line nurses use this function to record daily service log. The log includes regular care activities such as replacement of the catheter, stomach tube, tracheotomy tube and general wound dressing; unexpected activities like emergent hospitalization or emergent CPR (cardiopulmonary resuscitation), and other information such as accidents in transit. This information can be used for further follow-up to patient condition for enhanced care service.

(3) Patient management module has the following functions:
   a) Patient registration
      New patient registration is accomplished through the registration function. Every new patient data needs to be validated by the authority before entry to the database.
   b) Patient health evaluation
      This function provides the nurse with a pre-defined checking menu to evaluate patient current health condition. The evaluation includes: consciousness state (e.g. consciousness, restlessness, delirium, stupor, vegetative state), emotional state (e.g. stable, depression, anxiety), expression ability (e.g. verbal communication, body expression, communication aids, no communication ability), respiratory status (e.g. self-breathing, oxygen delivery masking, tracheotomy intubation, mechanical ventilation), dieting condition (e.g. self-feeding, assisted eating, stomach tube feeding, intravenous injection), and excretory function (e.g. self-excretion, assisted excretion, incontinence, retention catheters, and colostomy).
   c) Service satisfaction rating

In order to continuously improve the home care services, the hospital needs to collect and review patient's care experience. Through this function, patients and family members can fill out an online survey to reflect their satisfaction with the care services.

The home care work scheduling method

The work scheduling included two stages: (1). Patient clustering, and (2). Work scheduling. The first task for the home care scheduling was to cluster patients based on their home locations and service items. Thereafter, the system matches a nurse to each cluster of patients. Basically, the matching process is to solve the so called "Multiple Travelling Salesman Problem (MTSP)" [1,5].

Patient clustering

Clustering is a commonly used method to discover the separation of a set of objects into an unknown number of

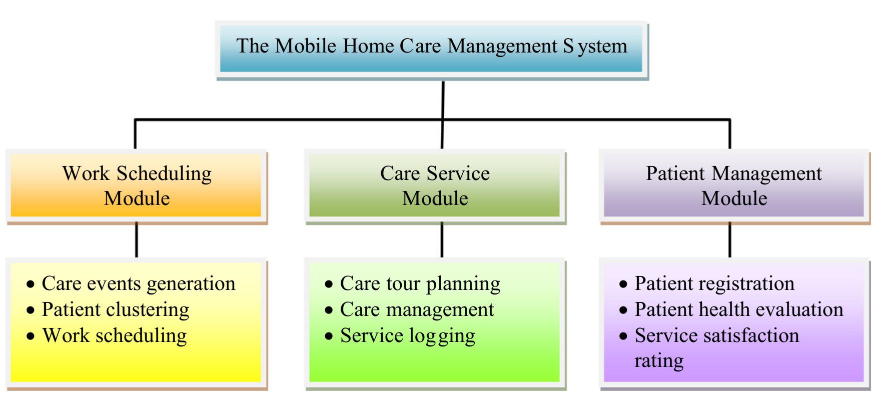

Figure 1 The function structure of the mobile roaming sessions of home care management system.

subsets while minimizing intra-cluster variation and maximizing the inter-cluster variation. In this study, we first categorize patients into several groups based on their homecare service items (e.g. replacement of the catheter) and care cycles (e.g. once per week). Then and there, we apply a genetic *k*-medoids clustering algorithm (GMCA) to cluster patients [25]. The GMCA applies a heuristic operator to select k-medoids from the data set and efficiently minimize the total dissimilarity within each cluster. When compared with previous genetic algorithm based k-medoid clustering approaches such as genetic clustering algorithm (GCA) and random assorted recombination genetic algorithm (RAR_wGA), the clustering problem was defined as: "given a data set $X=\{x_1, x_2, \ldots, x_n\}$ with n data objects, clusters of the *k*-medoids model are generated by selecting a set of k members of X as "medoids", and assigning each non-selected member of X to its closest medoid".

Details of the patient clustering was described in the Appendix A.

Work scheduling

Based on the clustering results obtained in previous stage, the system applies Carter and Ragsdale [5] genetic algorithm to generate the home care schedule for each nurse. The final schedule should be satisfied two criteria:

1) A nurse has the shortest total travel distance to a cluster of patients, and
2) The visit schedule fits every patient requested service date (e.g. Monday/week).

Similar to the patient clustering, the scheduling genetic algorithm includes six main steps: (1) Encoding, (2) Evaluation of adaptation values, (3) Selection and duplication, (4) Crossover, (5) Mutation, and (6) Termination condition.

The genetic scheduling algorithm worked well to generate the home care schedules. Details of the genetic algorithm was described in the Appendix B.

Results and discussion

Interview results for system requirement

Based on the results of focus group interview and questionnaire, we found that improper work scheduling was the main problem. Currently, a monthly working schedule was generated by the head nurse, and every nurse was assigned equal time to look after the elderly based on the pre-arranged schedule. There were several drawbacks using this method. First, not only the scheduling had to be performed manually which took a lot of time and manpower, but it also did not optimize the work loading. In real situations, patients were distributed in different geographic locations. Sometimes, a nurse spent too long to travel to a home. The travel time to a care recipient was not considered in the scheduling. Second, when a nurse needed to spend more time with the patient, current scheduling method was not able to dynamically reschedule the work load. The increase in time pressure led to a reduction in care time per care recipient as well as the fragmentation of care work. Finally, the schedule system did not store information about how much time a nurse spent on a patient and why the patient needed more time for care. The data could be used for a physician to trace the patient's health condition for follow-up care.

Besides the work scheduling issues, nurses were not able to access related documentation or knowledge to assist their work at the point-of-care. Particularly with patients who had emergent cases, timely knowledge sharing is very important for the care. In addition, care data charted in paper-based forms is hard to preserve and not ready for further data analysis.

System implementation

Software and hardware

We used AppServ to install software tools including Apache, PHP, MySQL for the care service module development. We applied Microsoft Dynamics CRM (Customer Relationship Management) to develop the patient management module. We also used PHP plug-in software with Google Map API to create the care route planning function.

Regarding the hardware, the home care nurses used smartphones to access care service functions such as care route planning, patient health evaluation, care management and service logging. Three major smartphone operation systems included Android, iPhone OS, and Window Mobile as acceptable devices to link to the home care system.

A care service scenario

A case scenario is used to describe how the system works. In this case, there are six nurses to look after 102 patients in Taichung County, Taiwan. The home care services start with work scheduling. Firstly, the head nurse uses work scheduling module to generate a month work schedule for nurses (see Figure 2).

Basically, the system uses the Section 2.3.1 method to cluster the patients into 6 groups as shown in Figure 3. Each cluster has 17 (=102/6) patients. Then thereafter, the patient scheduling genetic algorithm (see Section 2.3.2) is used to generate the work schedules for nurses. When the work schedule was generated, nurses could use their smartphone to check the assigned schedule (see Figure 4).

Table 1 showed the first two day's work schedule (June 1&2, 2013) for a nurse. On June 1, the nurse will visit 5 patients whose id number is 3182, 822, 3767, and 2492 in that order, and the corresponding care event number is C068, C060, C066, C102, and C047, respectively. The cell in fourth row, fifth column showed the Euclidean distance between the hospital and the first patient's residence, and the distances between patients. For example, the distance between the hospital and the patient ID of 3182 (C068) was 2.03 km (=0.0203*100 km). The total travel distance for the nurse to visit 5 patients was 8.23 km.

Since the traffic in Taichung downtown was very busy, the nurse can use tour planning function to help arrive at the patients' homes. The program embedded in the smartphone was able to detect the nurse's current location via the GPS antenna and passed the information to the system application web server to retrieve map and routing information from the Google Map server (see Figure 5).

When the nurse reached patient's home, the care professional could use patient care management function to access patient

Figure 2 The system login page and the schedule start & end date setting.

Figure 3 Patient clusters (Taichung downtown Google map, Taiwan).

personal information that included current health condition, special care requirements, patient family's notes and expectations, and particular precautions, etc... (see Figure 6). Only the care nurse or doctor of this patient could login in to review the information, which was in accordance with patient privacy law.

After the nurse completed the home care service, she uses service logging function to record daily service activities (e.g. replacement of the catheter), unexpected activities, and other information like accidents in transit (see Figure 7). This information can be used for further follow-up enhanced care service.

At the management side, the hospital manager/head nurse used the patient management module to maintain patient personal information, current heath condition, service items, and other related information (Figure 8).

System usability evaluation

To evaluate the usability of the mobile home care management system, we interviewed several users including hospital manager, head nurse, and two front line nurses. The interview results were categorized and summarized in the following comments:

a) System benefits to work scheduling:
   - "The automatic care schedule generating function dramatically reduced my workload and decreased scheduling errors. It also made nurse care schedule very flexible. When a nurse needs to spend more time with the patient, we can dynamically reschedule the work load."

b) System benefits to patient management:
   - "The patient care management helped me to easily manage patient personal information, to access related documentation or knowledge to assist my work at the point-of-care. The service logging function allowed me to record daily care activities. Those functions have improved my service quality."
   - "I can use my smartphone to access patient health data at the patient's home which was very good for my work. The only concern was if the system had strong

Figure 4 Nurse can check assigned schedule from the system main menu.

Table 1 The work schedule for a nurse (only show first two days of schedule)

Date	Orders				1	2	3	4	5		Total distance
		Card no.	ID		3182	3017	822	3767	2492		
6/1			Distance	Medical Record No.	C068	C060	C066	C102	C047	Hospital	
			Medical Record No.								
			Hospital		0.0203						
	1	3182	C068			0.012					
	2	3017	C060				0.013				
	3	822	C066					0.0106			
	4	3767	C102						0.0067		
	5	2492	C102							0.0197	
	Total distance				0.0203	0.012	0.013	0.0106	0.0067	0.0197	0.0823
Date	Orders				1	2	3	4	5		Total distance
		Card no.	ID		3545	155	1804	3018	3135		
6/2			Distance	Medical Record No.	C083	C023	C020	C060	C066	Hospital	
			Medical Record No.								
			Hospital		0.0186						
	1	3182	C083			0.0297					
	2	155	C023				0.0182				
	3	1804	C020					0.0162			
	4	3018	C060						0.013		
	5	3135	C066							0.0203	
	Total distance				0.0186	0.0297	0.0182	0.0162	0.013	0.0203	0.116

Distance unit: 100 km.

data security mechanism to protect patient data privacy."

- "Service satisfaction rating collected patient's service experiences. The review data reflected patient's requirements and expectations. I can use the data to improve my service quality."
- "The mobile service logging function helped me to record important care activities, time spent on a specific case, working experiences, unexpected events and other information such as emergency schedule change. The log can be used for further follow-up and to enhance my care service."

c) System benefits to tour planning:

- "The tour planning function saved me much travel time and cost. I can use my smartphone to show the patient's home location map and the planned route to reach patient home. However, the map did not show patient's service item/type so that I can prepare myself before visiting the patient. I hope that the system can add this service to the tour planning function. "

Figure 5 The tour planning function. (1) tour plan from hospital to patient A, (2) the route from patient A to B, and (3) full tour plan to visit all patients.

d) System usability in general:
- "Sometimes it is very difficult for me to use the (small) smartphone screen to view information and operate complex data input. A simpler interface design such as a checkbox selection for service information input would help my work."

Fig. 6 The patient care management function.

Figure 7 The service logging function.

- "The system integrated mobile technologies with our current information systems has improved the elderly home care services and management."

Based on the above end user commentary, we found that care scheduling, care management, tour planning and service logging function were most useful features for improving the home care service for the nurses, especially. However, one user found that the small mobile phone screen was a limitation of the system usability.

Finally, it is important to note that with a bigger using sample, there are other potential issues likely to emerge such as user training, error handling, reliability and security issues. Have this in mind, our future work is to recruit more participants to test the system usability, and use systematic methods such as "think aloud" method [16] and System Usability Scale (SUS) to evaluate the system.

Discussion

As indicated by Mergen et al. [20], there are two types of home care: acute home care and post-acute/rehabilitative care. The first care type involves active medical management of a serious disease. There, the patient is hospitalized and the physician's role is dominant. The second type differs from acute care in that its focus is on retrieval of functions and completing convalescence. Nurses are the first-line main players. In this study, the X-hospital mainly provides post-acute/rehabilitative care. Therefore, the system workflow is designed to fit this case type's business process, i.e. the IT accessibility design is in accordance with the requirements of mobile roaming session home care service. The first type of acute home care is, therefore, not currently considered in the present study.

In the time of system testing, home care nurses used small screen smartphone to access the application. The small screen did not have adequate information display. Also, it was not easy for user to operate data input [22]. To deal with the challenge, we recommend the hospital should equip front line nurses with iPad or wide screen iPhone for application in the future.

Another system constraint was that users may not be able access to the Internet to use the system functions and resources to perform their work at some rural areas. However, in this study, since all patients are in Taichung urban areas with very good wireless networking infrastructure, there are no network access issues.

At the service end, Stone & Dawson [29] described the direct care workers as "the eyes and the ears" of the health care system as they work in a patient's home, working (typically) one-on-one with their clients. Nevertheless, there are many technical and non-technical factors. To deal with the challenges, many published studies have recommended applying information and mobile communication technology (IMCT)

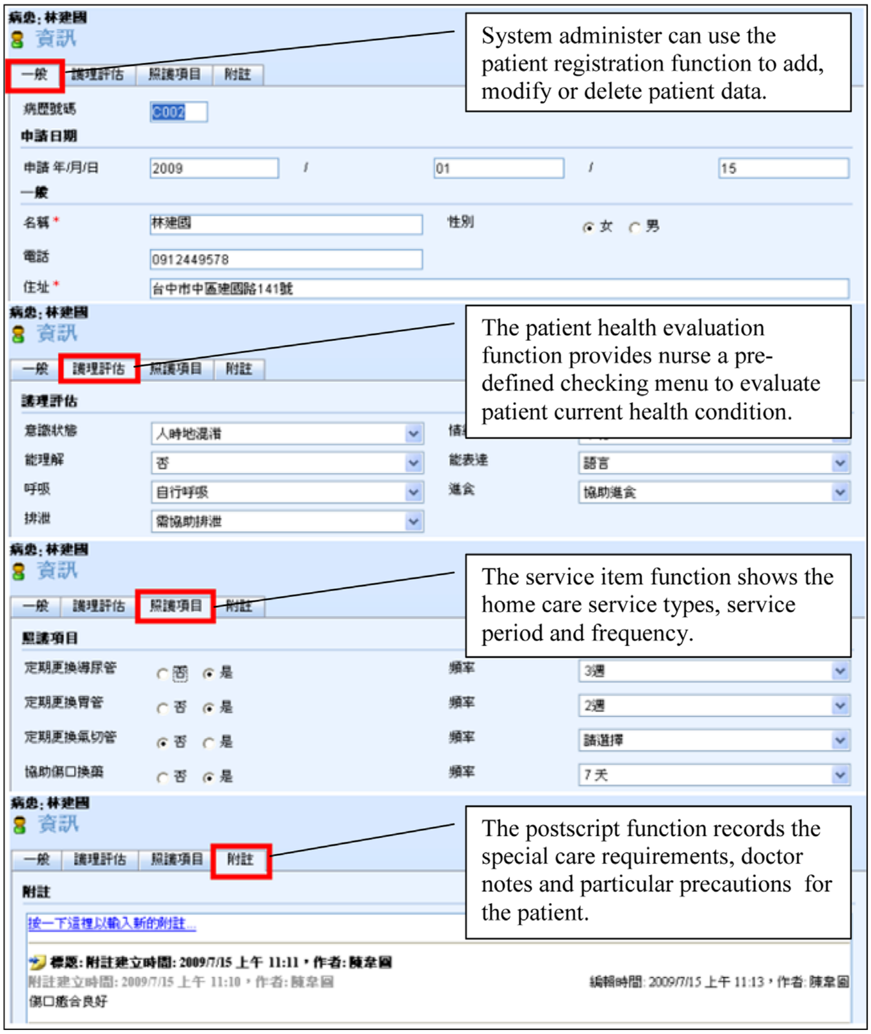

Figure 8 The patient management module.

to enhance the elderly home care services. Unfortunately, in many countries, small- to medium-sized hospitals or home care centers usually have limited budget to construct comprehensive information infrastructure or invest in advanced IT facilities to support the service.

Conclusions

In this study, we apply IMCT to develop a mobile roaming sessions of home care management system to help first-line nurses efficiently deliver care service. The patient management module with several functions was found to be mainly used to continuously strengthen hospital-caregiver-patient relationship and improve service quality. We also found that the utilization of a Service Oriented Architecture (SOA) to design the system structure allowed the mobile product and its tools to combine aggregates of functionality to form the *ad hoc* application built almost entirely from the hospital current software [2]. This minimized the hospital's IT investment.

Sometimes, users may have difficulty accessing the system resources if they visit patients at some rural areas where there is no wireless networking infrastructure. To address the limitation is our future research work.

Finally, the information about actual time and cost saved by using the IMCT system in comparison to the previous service delivery model is crucial to evaluating the success of the newly developed IMCT system. However, due to time constraint and participant scale, it was not addressed in the current study.

Author statements

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No funding was received for this study.

Competing interests

The authors declare that they have no conflict of interest.

Ethical approval

Not required.

Authors' contributions

All the authors have contributed substantially to the material and/or intellectual content, data analysis, if applicable, and the writing of the manuscript, sufficiently to accept public accountability for it.

Appendix A. Patient clustering algorithm

The patient clustering includes six main steps, as follows:

(1) Encoding and population initialization

When we start to solve clustering problems with the genetic algorithm, and at this point we need to encode chromosomes. In this study, the chromosome length was the total number of patient clusters that is equal to the number of nurses. If there are K nurses to take care of X patients, then the chromosome length equalled K. Each chromosome was then assigned a number in $1\sim K$. The chromosome code cannot be duplicated, otherwise it is considered as an invalid chromosome coding. For instance, there are 4 nurses (n=4) to watch over 60 patients in a certain working period. Followed by the patients (7, 10, 35, 59) being encoded in 4 clusters where the 7th, 10th, 35th and 59th patient were selected as medoids as shown in Figure A1.

Next, we randomly select patient number x_1, x_2, ..., x_k to be medoids, and evenly assign non-selected patients to each medoid. This completed the population initialization.

(2) Evaluation of adaptation values

In this step, we applied a Dissimilarity Measure method to evaluate the fitness value. Each patient's home location was determined by a set of longitude and latitude data, and the distance between a patient and the medoid was measured by the Euclidean Distance. The sum of all distances between patients and the medoid, i.e. the Sum of Euclidean Distance (SED) is the dissimilarity of the cluster. The lower the SED value is the better fitness of the chromosome, and higher possibility to be retained in the evolving process. The distance fitness function is defined as in step (1):

$$SED = \sum_{i=1}^{n} \sum_{j=1, x_i \in C_j}^{k} d(x_i, m_j) \qquad (1)$$

where:
C_j : the j cluster, j = 1,2,...,k.
m_j: the mediod of cluster C_j.
x_i: the i patient home location, i = 1,2,...,n.
$d(x_i, m_j)$:the Euclidean Distance between i patient home and j cluster mediod.

K_1	K_2	K_3	K_4
7	10	35	59

Figure A1 The chromosome encoding structure.

(3) Selection and duplication

In this third step, the roulette wheel selection method was used to calculate the fitness value of each chromosome and the sum total of all chromosome fitness values, i.e. the roulette wheel area. The bigger the chromosome's percent in the roulette wheel area, the more likely the chromosome will be selected to be the next generation. Then, the chromosome selection probability was defined from step (2):

$$P(x_i) = \frac{\text{Fitness}(x_i)}{\sum_{j=1}^{n} \text{Fitness}(x_i)} \times 100\% \qquad (2)$$

where:
$P(x_i)$: the i chromosome (x_i) selected probability
Fitness(x_i): the i chromosome fitness value
$\sum_{j=1}^{n}$Fitness(x_i): the sum total of n chromosome fitness values

The next step was to generate a second generation population of solutions from those selected through a combination of genetic operators: crossover and mutation.

(4) Crossover

Crossover is a genetic operator used to maintain genetic diversity from one generation of a population of genetic algorithm chromosomes to the next. In this step, we used a single point crossover to produce a new generation of solution. Using this crossover method, a single crossover point on both parents' organism strings was selected. All data beyond that point in either organism string was swapped between the two parent organisms. There was a pre-defined crossover probability. When a random generated startup probability was greater than the pre-defined crossover probability, the crossover process was triggered.

(5) Mutation

Mutation was also a genetic operator used to maintain genetic diversity. The mutation substitutes for the chosen gene by another randomly generated gene, subject to the restriction that the new gene was not presented in the current gene. In the study, we applied a flip mutation to the offspring. When the startup probability was greater than a pre-defined mutation probability, the mutation process was triggered.

(6) Termination condition

The generational process was repeated until a termination condition had been reached. In this study, the termination condition set was one hundred evolving generations. The fittest chromosome seen in the last generation provided the best solution to the clustering problem.

Appendix B. Work Scheduling Algorithm

The work scheduling genetic algorithm includes six main steps:

Day 1					Day 2					…	Day 10				
L_1	L_2	L_3	L_4	L_5	L_1	L_2	L_3	L_4	L_5	…	L_1	L_2	L_3	L_4	L_5
001	022	033	034	045	006	017	018	029	030		005	012	015	038	050

Figure A2 Encoding of care schedule and population initialization.

(1) Encoding

A chromosome was the scheduling solution. Let W be the working day per month (e.g. 10 days) and L be the working load per day (e.g. 5 patients to be look after) for a nurse. Then the chromosome encoding architecture was as shown in Figure A2. For example, a cluster includes 50 care events encoded as 001, 002, 003, 004…050; therefore, five events (001, 022, 033, 034, 045) were randomly filled into day one schedule. Using the similar method, the system completes chromosome coding and population initialization.

(2) Evaluation of adaptation values

There were two factors for the evaluation of adaptation value (fitness): the distance fitness value and the date penalty (see Eq. (3)).

$$\text{Fitness} = D + T \tag{3}$$

where:
D: distance fitness value.
T: date penalty.

The smaller the adaptation value, the better the adaptation of this chromosome would be and the higher the probability it was retained.

The distance fitness value D was determined by Eq. (4):

$$D = \sum_{i=1}^{W} \sum_{j=1, x_j \in W_i}^{L} d(x_j, x_{j+1}) \tag{4}$$

where:
W: total working days of a scheduled period (e.g. a month);
W_i: i working days, $i = 1,2,\ldots,W$.
L: assigned patients for each nurse.
x_j: j patient home location, $j = 1,2,\ldots,L$.
$d(x_j, x_{j+1})$: the Euclidean Distance between two adjacent patient homes in a cluster.

The date penalty function in Eq. (5) was used to calculate the similarity between the assigned patient visiting date and the patient preferred home care service date. The bigger the value the more severe penalty will be given.

$$D = \sum_{i=1}^{W} \sum_{j=1}^{L} |(w_i - x_j)| \tag{5}$$

where:
W: total working days of a scheduled period (e.g. a month);
W_i: i patient visiting date (e.g. 24-April-2014) , $i = 1,2,\ldots,W$.
L: assigned patients for each nurse.
x_j: j patient preferred home care service date (e.g. 23-April-2015).

(3) Selection and duplication

The Eq. (2) was used again to determine the chromosome selection probability.

(4) Crossover

Different from the single point crossover method used in the previous genetic k-medoids clustering algorithm, the scheduling genetic algorithm applies two point asexual crossover. Any two points were selected for exchange in the same chromosome to generate a new one. Again, there was a predefined crossover probability. When a random generated startup value was greater than the pre-defined probability, the crossover process was triggered.

(5) Mutation

In the algorithm, we applied a flipped mutation that created a new generation of a population. When the trigger probability was greater than a pre-defined value, the mutation started to commence.

(6) Termination condition

The termination condition set for this algorithm was one hundred evolving generations. When the termination condition was met, the result was the most suitable service schedule.

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