A New Portable Home Nursing Care Support System with Scheduling and Flexible Real-time Routing Mechanism

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Abstract

With the rapid growth of the elderly population, the need for long-term medical care continues to increase, and reliance on medical and institutional nursing care services is limited. Long-term nursing care at home is a kind of home care service which provides continuous nursing care after discharge from the hospital and is an alternative long term care choice that can relieve the hospital from the pressure of too many long-term care beds. Therefore, how to integrate limited medical resources and create a mobile home care model that attracts more manpower willing to devote themselves to the long-term care service and can upgrade the value of nursing information system has always need a breakthrough in the medical information field. This research is built upon the mobile computing technology to construct a new portable home nursing care support system. The result shows that this mobile home nursing care support mechanism can help patients and their families maintain good quality of life and dignified living. At the same time, caregivers are provided with intelligent guide and medical information support during their implementation of home care medical measures, thereby excluding redundant non-professional medical details and improve the quality of home health care service.

Keywords: Long-term home nursing care, Mobile healthcare platform, Tabu search algorithm, Adjustable path scheduling

1 Introduction

Presently, as a result of the advancement in medical technology and the higher health awareness of the people, the average life expectancy of human beings has risen and the population ratio of the elderly has increased drastically. The caring of the elderly has become a major issue of society. Living a long healthy life has always been a goal people pursue; however, the lifespan may have been extended but the condition of the body (torso) may actually be gradually declining. Caring for the disabled/incapacitated has become a high-burden social demand. Caretaking is in itself a high cost, high pressure, multi-faceted job that renders many medical institutions or independent home care agencies unwilling to offer home nursing services. The government has repeatedly called for ardent commitment into long-term care service by medical institutions but to of no avail.

The long-term care system in Taiwan can be classified, based on the type of service resources, into home, institution, and community models. Hospitals are mainly responsible for emergency and the severely ill and have limited resources while institution type has a high cost and limit in the quantity of services. The community model mainly serves home patients yet relies on medical institutions and cannot operate independently. Consequently, the home nursing supported by connecting with medical agency and receiving medical information has become an important service option in the development of long-term care. Frequently seen services are intubation (nasogastric tube, catheter, tracheostomy tube), wound treatment, direct medical care, and home rehabilitation [1-2]. Home nursing care is sending professional nursing personnel to the home of the patient to maintain the optimal working function of the patient. According to research reports, the elderly highly prefers home type care, institution type the next, and community type the last. The reason may be that the home type offers more advantages over the other service types, including lower economic burden, retaining the integrity of the family, alleviating the time and energy of the care provider, avoid the chance of re-hospitalization due to incomplete treatment [3-4]. The current development status of home nursing care in Taiwan is based on the reimbursement standard of the medical service principle of the National Health Insurance--classified into patients requiring regular care services and patients requiring special care services. Home nursing care needs mutual cooperation between the doctor and professional nursing personnel [5]. The services they provide include tracheostomy, vesicoclysis, or ostomy care. The detailed service items for special and regular care services as illustrated in Table 1. The government offered some relevant benefits and regulations in order to effectively reduce the burden of the care providing family including 95% reimbursement by the National Health Insurance, up to two home visits per month (maximum up to 4 times), a limit

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of four month for each case (extendable depending on the severity of the illness). Moreover, the government sets a limit of 100 home visits per month per home care nurse to ensure the quality of home care.

Table 1. Service items of home care

Special care items	1.	Tracheostomy care
	2.	Catheter detention
	3.	Nasogastric tube detention
	4.	Vesicoclysis
	5.	3rd and 4th stage pressure injury care
	6.	Large quantity fluid intravenous injection
	7.	Ostomy care
Regular care items	1.	Oral care
	2.	Regular health checks up
	3.	Nursing instruction
	4.	Alcohol rubbing bath, mint rubbing
	5.	Small dose injection
	6.	Passive joint exercising
	7.	Other care items

(Source: National Health Insurance Part 5 Home Care Description)

The current ways of applying for home nursing care are in-hospital referral, out-house referral, application by family member, and institutional referral. Once an application is approved, the home care nurse will receive information on the applicant and will conduct type-1 home visit to assess preliminarily the family situation and need before closing the case. Next, the home care nurse will arrange nursing service based on the intubation (nasogastric, catheter, etc.) demand. However, the home care nurse can only manually record the content of each visit, for example, time of tube change, material. The nurse must also manually calculate the date and restrictions until the next visit. The nurse, under time pressure between the two locations and without support by the information system, may have forgotten to record important notes resulting in diminished care quality, medical dispute and rendering the time duration for home care nurse to stay at the job to be short and that fewer people would be willing to enter the industry, if use the information assistance systems will help improve the working environment of nurses [6].

Normally speaking, the basic action of a home care nurse before visiting is to review the addresses of daily itinerary. Usually, the home care nurse will adjust the schedule based on demand and urgency, when there are more cases for a day, it becomes hard for the nurse to arrange the best and most efficient itinerary route. This creates fatigue and inefficiency for the nurse. The research of the scholar Hasson shows that by decreasing fatigue in the nurse, the satisfaction rate will increase; conversely, the greater pressure, the smaller the satisfaction rate and the higher the quitting rate [7]. In fact, automated scheduling can help alleviate the economic burden and cost of an individual or a hospital while increasing the safety and flow of the nurse working. C. E. Boone et al shows that scheduling systems with automated reminder can be a practical, cost-effective, and easily scalable strategy to increase clinic's ability to care for more patients without appreciably expanding staff or resources [8]. Even more is that in actual practice, the home care nurse usually takes a taxi to the home of the patient so that the distance will be calculated into the cost of service. Therefore, travel time planning is related to distance and service time and factored into calculation [9].

Scheduling the itinerary is usually another important task of the home care nurse. The scholars G. Carello and E. Lanzarone think the main directions should be planning of case execution (including itinerary management) and route arrangement [10-11]. The pairing of the home care nurse with individual case usually takes into consideration of locality meaning that the arrangement of every patient was made certain by the region/locality of each nurse [12]. If the nurse received an emergency call during a visitation process, pairing by locality will let the nurse resolve the emergency with higher efficiency and speed [13]. However, regular case is usually serviced by the same home care nurse over a long period of time. The continuity of such nursing behavior is typically regarded as a goal and not a serious condition request. The nurse may change the home visit itinerary due to a sudden incident and asked the help and support of another nurse [14]. Therefore, real time information updating and notifying the home care nurse are very important. Most of the visit schedule planning is arranged by day as basis in order to meet the actual demand [15]. In 2006, Stefan Bertels, for solving the problem of home health care, constructed mathematical model and underwent calculations using linear programming, constraint programming, and heuristics, plus compared the execution efficiency among various heuristics (tabu search, simulated annealing algorithm). The result showed that simple mixed heuristics can attain the best solution in which constraint programming with tabu search mixed algorithm will produce the best result within a time constraint [11]. Chananes Akjiratikarla employed particle swarm optimization algorithm to help minimize the total route distance of home health care and satisfied many British limiting conditions [15]. Emna Benzarti developed a mathematical model to solve the dispatching problem of home care. The model takes into account the work load of the nurse and relative distances [12]. Stefan Nickel used the constraint programming and heuristics to construct the timetable for the nurse to facilitate the nurse to execute work according to the timetable [14]. The research of Ettore Lanzaronea proposed a home care dispatch continuance solution. Recent researches have started to focus on providing multiple options of routes for the nurse to the patient's home [16] and optimization of pairing the patients with the total driving routes into the model [9], so the problems encountered in home care will be gradually resolved.

As for calculating the shortest distance, tabu search is the most efficient way. Tabu search (TS) was a heuristic algorithm proposed by the American scholar, Fred Glover in 1989 [17-18]. It mainly explores all possible solutions from the present location to the proximal point and continuously iterate and re-calculate until the stopping condition is satisfied. Simply put, it is an overall algorithm of gradually searching for the best solution. TS produces the best solution through a special tabu list (TL) and related principles to avoid repeat searching [19]. With repeating iteration and the internal moving record of TL plus aspiration level, the best possible combination will be arrived through the entire iteration moving process.

In the development of information assisted clinical application, Mu-Hsing Kuo *et al* used service-oriented architecture (SOA) to help with the dispatch problem for the front-line nurses [20]. Mohammed A. Awadallah *et al*, through ant colony optimization, effectively distributed nurses to all service locations and solved the problem of dispatching multi-day schedule for the labor force [21]. In order to enhance the efficiency of the medical care, some scholars focused on offering multiple options of nurse's routes to the patient's home to attempt to lower the workload of schedule planning [16]. Yet, the technology and concepts proposed by the scholars are hardly in the form of a total solution that provides comprehensive nursing information-assisted clinical home health care.

Therefore, integrating wireless transmission and information development technology to effectively broker the medical profession and construct a medical grade mobile home care support platform will not only provide appropriate information support to the nurses undertaking home health care to alleviate the workload of information exchange but also elevate the autonomy of the care that satisfies the need of the patient to help the family and patient maintain a good quality of life.

2 Methodology

In this study, we construct an effective nursing information support system which includes (1) Analysis of current clinical practice that corresponds to the current clinical situation, (2) A process-based module planning for home nursing care. (3) Support of intelligent information calculation. This proposed system is aimed to assist nurses providing home care services to improve the quality of medical services and to reduce nurses' work load.

2.1 Analysis of Current Clinical Practice

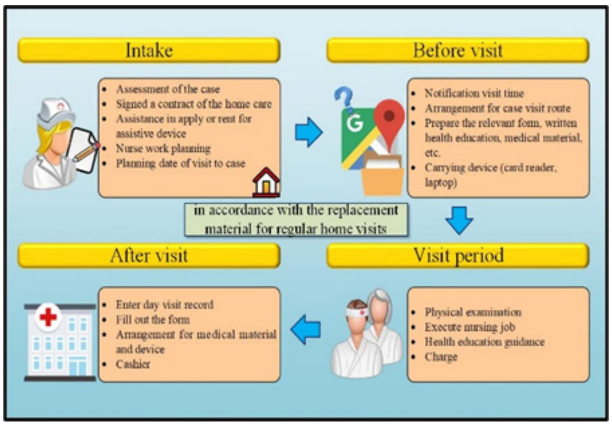

Figure 1. Work flow chart of home care

Evaluating the need and supplying the service based on the situation of each individual case is the important bridge between the feasibility of the actual nursing operation. Especially with the intervention of information technology, more attention should be given to the logics of using such technology in actual environment including the real needs of the care giver and receiver. Figure 1 presents the work flow of current home care situation, including receiving application, pre-visit, visiting, and post-visit. The work details are illustrated in Figure 1 as well.

First, the needing patient will apply for home care service at a certain medical institution according to related regulations. This means that the hospital will have a new case to be arranged into the schedule of a nurse for regular care (for example, changing nasogastric tube, catheter, tracheostomy tube). When the hospital has made certain of the newly established case, the head nurse must decide which home care nurse is suitable in terms of related regulations and location plus if the number of services the nurse provided last month was too high. If the head nurse arranges too many services for a nurse, the insurance payment will be discounted (the Taiwan government set a limit a 100 services per nurse per month to ensure service quality). Table 2 is the basic regulations regarding home nursing care of a certain regional hospital in Taipei. The regulations are: no more than 100 services per month, early arrangement before holidays, finishing home care work before 5 o'clock, different case situation requiring different service schedule based on selection of medical materials.

The home care nurse must complete visiting all cases in order before going back to the original dispatching hospital or institution. Most of the home care work relies especially on smaller home care agency in order to supplement the medical services with hospital system at its core. Therefore, for the nurses, backend information support can actually reduce medical dispute and increase task execution efficiency. According to American National Institute of Standards and Technology, NIST, cloud computation is a model that can share and distribute computing resources in accordance with the need of internet access (for example, internet, server, saving, applications, and services). Such cloud service is exactly what a small home care agency/unit needs in terms of resource and information capability. Cloud computing has five important features including self-service produced with demand, diverse internet access, agility of fast re-deployment, resource-sharing resource pool, and computable services [22]. The research bases on the above five features to develop nursing scheduling information system so that the end user (be it a device, operation system or size of panel) can use flexibly according to his own need through internet. The objective is to optimize the pre-visit and post visit work of a home care nurse by utilizing web platform so the nurse can quickly look up the information on the family to be visited. Also, the nurse can conveniently plan for schedule and best routes to enhance the nursing quality and service efficiency.

Table 2. Required conditions and limitations of home nursing care (with a regional hospital in Taipei as an example)

Item	Conditions	Description
1	Nor more than 100 services per month per nurse	services = number of visits
2	Early arrangement before holidays	No services on holidays by the institution
3	Finish home care work before 5 o'clock everyday	To ensure the nurse having enough time to go back to the hospital for recording information
4	Different case situation requires different service schedule based on selection of medical materials	Nasogastric tube (rubber) = 14 days Nasogastric tube (silicon) = 30 days Catheter (rubber) = 14 days Catheter (silicon) = 30 days tracheostomy = 30 days

2.2 A Process-based Module Planning

Home care nurse can schedule daily visit itinerary through the e-calendar which will autogenerate the shortest route arrangement based on the nurse's schedule of the day and presented as Google Map graphic format with GPS road guide to lead the nurse to the patient's home. Combining the 'check-in' concept of Facebook to have a clear grasp of the nurse's current location will not only lead the nurse to correctly arrive at the home of the case but also facilitate the head nurse to call for backup in case of an emergency so the patient would receive the care he needs in the shortest possible time. As shown in Figure 2, the functions of the system in this research mainly include: itinerary planning, route analysis, service task confirmation, and statistical analysis modules.

2.2.1 Itinerary Planning Module

2.2.1.1 Case Management and Itinerary Planning

The itinerary of the home care nurse will be arranged based on the current information of the cases; therefore, the system has built in an 'add' function which includes adding, revising, and deleting a case. In order to increase the efficiency of the nurse's creating a new case file, the system provides

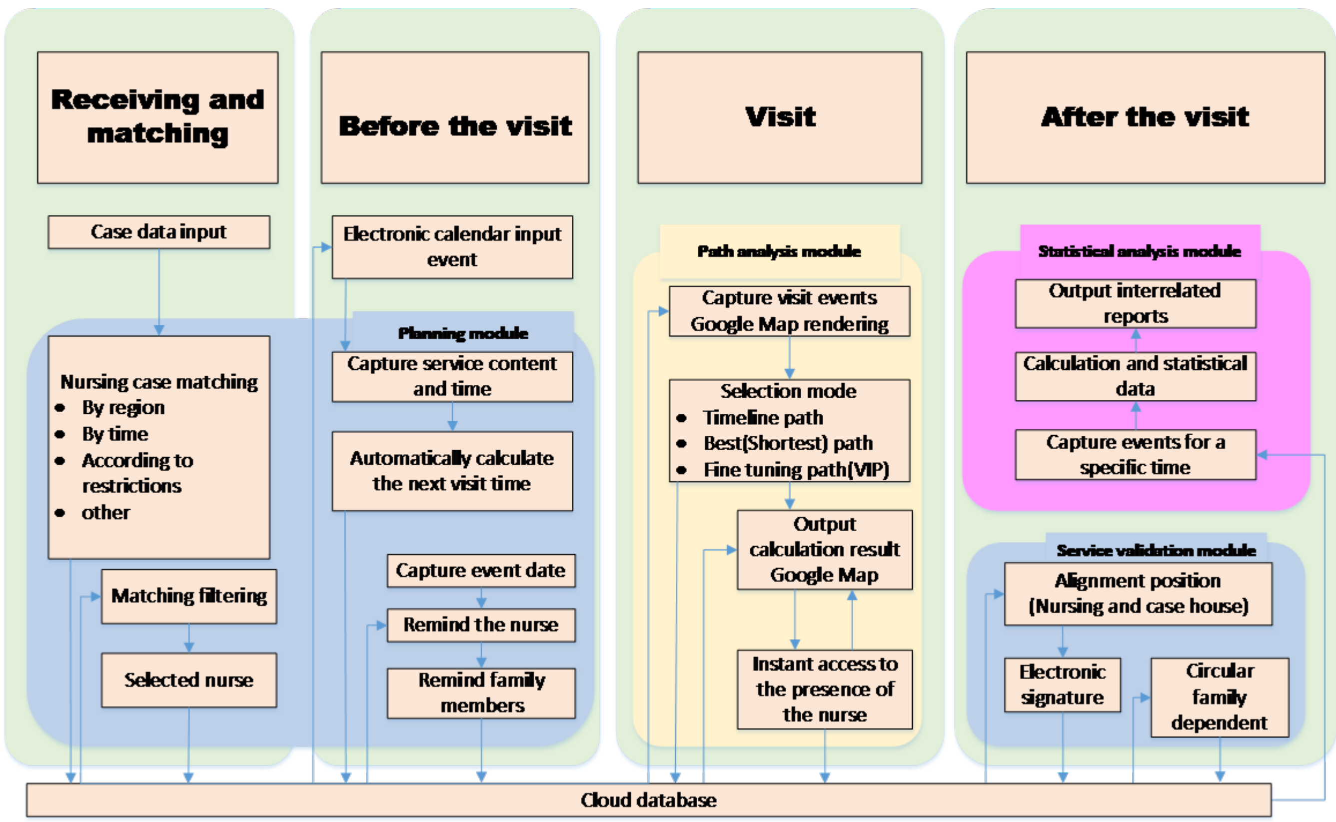

Figure 2. Functions of medical grade home care system structure modules

the nurse a set format file in which the nurse can import directly instead of inputting one case at a time to achieve multiple case information entry, rendering the system more user-friendly and more efficient case management. In terms of pairing, the current ways of applying for home nursing care are in-hospital referral, out-house referral, application by family member, and institutional referral. Once the head nurse receives a new case, the head nurse must take the appropriate action distributing the task. The system's pairing mechanism will automatically decide on the suitable home care nurse and import relevant experience rules to assist in decision making and make pairing faster and more efficient.

Currently, the home care nurses still manually record all information and plan their itineraries. Consequently, the information system simulates that of manual format to reduce habit change of the nurse when operating the system. When the nurse needs to arrange the time for the next visit, the nurse can click on the "automatically set next visit" function, and the system will check the material used for the current visit, the time of tube change in the database, directly retrieve the data and add the date of the current visit and then automatically produce the time and date of next visit. The nurse can view the correct time through the window and quickly finish planning the itinerary. However, in responding to the many cases the nurse has to face every day, the nurse must decide on the routes to the homes of the patients so the travel time can be effectively shortened and the burden of cost on the hospital or the family member may be reduced. Therefore, the system combines the Google Map service and automatically calculates the distances between the homes of the patients for the day. Through graphic presentation of the routes, the priority of order in patient, timetable, and micro-adjustment of the order can be visualized to let the nurse avoid spending too much time and effort in planning the routes.

2.2.1.2 Automatic Scheduling and Reminder Functions

The daily case itinerary, the tube materials, and the items requiring special attention are different from day to day. In order to effectively remind the nurse of the next day schedule, the system, through automatic schedule setting by the server, is set at 11:30 every night (temporarily) to send mails to all nurses who have visits the next day, notifying the nurse of the name, the material type of the tubes, and other related service information. On the other hand, the system offers the current location tracking of the nurse and authorization management functions so the managers will be able to easily supervise and coordinate during an emergency (such as undertaking quickest regional temporary dispatch when tube falling off or loosening that endangers the life of the patient occurs). This not only helps patients resolve dangers but also exclude the anxiety in the family members.

Moreover, the home care nurses have quite busy daily work schedule, besides the abovesaid itinerary planning, they need to fill out many forms and related information. In light of this situation, the system added an automatic mail reminder function by using Linux CentOS scheduling (crontab) to automatically execute already written PHP function which sends a mail at 1:30 in the afternoon every day to those nurses who have arranged visits the next day, notifying them of the itinerary and related patient information for the next day to achieve the function of reminder.

2.2.2 Service Task Confirmation Module—Smart Positioning Check-in and Confirmation Stamping

As describe above, the research combines Google Map and the GPS positioning function of W3C's API so the home care nurse only needs to open the webpage in his cell phone or tablet and the system will dynamically store the current position on the map into the database based on the accuracy of the positioning and certain calculation formula (the difference of the current distance and that of the last). Additionally, in order to ensure and maintain home care quality, when the nurse's current location is at that of a patient, the nurse only needs to click on the check-in button designed in the system which will automatically do the calculations to verify the distances. When the verified value (longitude of current position-longitude of verified position) + (latitude of current position-latitude of verified position) <=0.0002, the system will show a window for signature to ensure that the nurse has completed the visit service. After the patient or the care giver finished signing and clicked on 'enter', the system will display a 'check-in successful' message; conversely, if the value falls outside the range, the system will display a 'check-in failed, your position is not close to the patient's location'. With a successful check-in, the finished case will become green (blue if not 'checked-in'), and a check mark will appear in the lower right-hand corner of a human figure on the Map so that during an emergency, the operating nurse or supervisor can temporarily dispatch support.

2.2.3 Statistical Graphical and Visualization Presentation

Information visualization is to turn 'hard' information (numbers or texts) into easy-to-understand graphics. The system, based on the actual need of the clinical nurse and supervisor, displays the web page using graphic visualization and present the statistical results in an easy-to-understand fashion such as: already visited/ yet to visit numbers, emergency line-cutting service.

The displaying in the dashboard and even setting alert range in colors not only offer the home care nursing team to better utilize medical resources at the moment but also provide the supervisor a clear overall nurse work information as reference for time coordination, supervision, and overall management.

In addition, the route planning module is part of the smart information computation support development and is also the core of mobile home nursing care platform which will be introduced in detail below.

2.3 Smart Information Calculation Support—Route Planning Module

2.3.1 Itinerary Planning Optimization and Distribution Limits

In order to resolve the problem of home care, the research must undertake analysis of itinerary planning and distribution limits, which are classified into two areas. The first one is pairing of the home care itinerary with the needing patients. The second is the problem of route planning. The limits problem in pairing after receiving a new case and route planning are defined in mathematical symbols with which corresponding limits and calculation formula are established. The following are the formulas:

$$\sum_{i=1}^{n} H_{ij} \geq S_{limit}, \forall j. \quad (1)$$

$$\sum_{i=1}^{n} H_{ij} = P_{daily}, \forall j. \quad (2)$$

$$H_i + P_i = 1, \forall i. \quad (3)$$

$$H_{id} + H_{i(d+1)} \ldots H_{i(d+4)} \geq 1, \\ \forall d \leq m-5, d \neq w. \quad (4)$$

$$N_{rubber} + N_{silicon} + C_{rubber} + C_{silicon} + T \geqq 14. \quad (5)$$

$$d_{daily} \text{f} \;\; d_{limit}. \quad (6)$$

$$A_x = Y + (N_{rubber} \text{ or } N_{silicon} \\ \text{ or } C_{rubber} \text{ or } C_{silicon} \text{ or } T), Y \neq W. \quad (7)$$

Formula (1) is to ensure that each nurse does not exceed 100 services with a four-week (one month) time period. Formula (2) is the total number of home care nurses of the institution or of the available nurses for the day that needs to complete the service requirement of every case. Formula (3) is for maintaining the continuance of the home care. Every case will have a (paired) nurse. Unless there is an emergency, basically there won't be other nurses to serve the case. Formula (4) is to ensure the nurse does not work over 5 days a week and on holidays as according to current hospital convention which means that the days of service for the nurse are Monday through Friday. Formula (5) is for, besides the very first visit of receiving the case, bringing at least one of the materials for the tubes to undertake care service. Formula (6) is to ensure that the nurse would have enough time to return to the hospital for data entry after completing all visits for the day. And in order to comply with the actual execution regulations which we have planned, the research has set 5 o'clock in the afternoon as the default latest work time. If the arrangement if past 5 p.m., the arrangement will be automatically invalidated. The last is formula (7) which will automatically calculate the time and date for the next visit after completing each case of the day to ensure the quality of the home nursing care. The definitions of mathematical symbols are illustrated in Table 3.

Table 3. Definitions of mathematical symbols for case pairing and schedule planning

Item	Symbol	Description
1	m	Number of days for the month
2	d	Number of days each week, $1 \leq d \leq 7$
3	w	Holidays of the country
4	Y	Date of current home visit
5	Ax	Nest visiting date
6	H_{ij}	Number of times 'j' the nurse 'i' has visited
7	P_i	Home visit case 'i'
8	S_{limit}	No more than 100 visits within four weeks
9	d_{limit}	Deadline time of daily home visit set at 17:00
10	P_{daily}	The need of each daily home care visit
11	d_{daily}	The length of time of daily home visit
12	N_{rubber}	Number of days for changing rubber nasogastric tube (14)
13	$N_{silicon}$	Number of days for changing silicon nasogastric tube (30)
14	C_{rubber}	Number of days for changing rubber catheter (14)
15	$C_{silicon}$	Number of days for changing silicon catheter (30)
16	T	Number of days for changing tracheostomy tube (30)

2.3.2 The Shortest Distance and Flexible Mechanism Designs

In order to meet the demand for route planning, the research has designed an adjustable selection mechanism in which there are three modes: when a new case occurs, the timeline first-in first-out, micro-adjustment in an emergency cutting in of itinerary, shortest total routes. The concept designs of the three modes are shown in Figure 3.

2.3.2.1 Timeline First-in First-out

According to the interview investigation result, currently, the home care nurses execute home visits in the order as displayed in the timetable, the first-in first-out mode. This mode will automatically store all locations of the day of the nurse into the server, which will convert the addresses into longitude and latitude values and display the values on the Google Map. The server will also arrange the nurse's sequentially so that the nurse does not have to enter the addresses one at a time while also planning routes. Moreover, in order to let the head nurse have a clear grasp on the current locations of all the nurses, the server will record the current position of the nurse according to the timetable automatically recorded. If the home care nurse cannot find the correct location of the case, the system has a built-in navigation function that can dynamically generate corresponding route list and guide with the coordinates on the map so the nurse can quickly know the distance and relative position of the patient's home from the nurse.

2.3.2.2 Micro-adjustment in an Emergency Cutting in of Itinerary

Most cases of home care are of disabled underprivileged. When an emergency arises, serious injury may occur if there is no immediate assistance. Therefore, if there is flexibility of emergency micro-adjustment for the supervisor, execution of nursing tasks and resolving emergencies will definitely be much more effective. When the supervisor micro-adjusts the execution order of the tasks in case of an emergency (activating emergency cutting in of itinerary micro-adjustment mode), the system will change the change of order command to the server after receiving change in information parameters to undergo re-arranging calculation and quickly generate the most appropriate route suggestion before transmitting in real time to the home care nurse the corresponding graphic instruction.

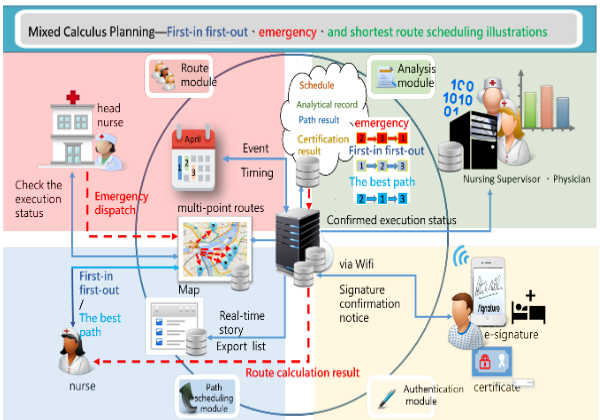

Figure 3. First-in first-out, emergency, and shortest route scheduling illustrations

Some hospital will absorb the transportation fees (taxi, fuel, or shuttle bus) of the nurse's going to the home of the case in order to respond to the transportation costs of dispatching service. Because the total distance is directly proportional to transportation cost, over a long period of time, the transportation cost would become a substantial cost to the medical institution. In order to lower the overall transportation cost, the research planned to use tabu search algorithm plus conditional judgement to calculate the shortest total routes. This function will be built into the mobile home care itinerary computation formula. The research will continuously verify and optimize the functions so the support platform can automatically calculate the optimized order of the visiting routes and display the addresses on the Google Map in a graphically visual fashion and the result is shown in Section 3.

2.3.3 Shortest Route Algorithm

Tabu Search, TS was a heuristic algorithm first proposed by the American scholar Fred Glover in 1989. It mainly explores all the possible solutions for moving from the current position to the proximal point and continuously refresh and recalculate until the stopping condition is satisfied. Simply put, it is a type of comprehensive gradual search optimization algorithm. Through certain Tabu List, TL to store the structure and related principles, TS will be able to avoid repeat search and fall into local optimal solution during the search process. Using repeating iteration and the moving record in the TL plus aspiration level, the optimized permutations will be generated during the entire iterative movement.

Using a traveler visiting various sight-seeing locations as an example, assume the traveler would want to visit 5 sight points from his current sight location and return to the original position, then all the sight points are $C_{total} = \{C_1, C_2, C_3, C_4, C_5, C_6\}$, in which C_1 is the current sight location of the traveler. Now the traveler needs to know which sight point should be the best to go. However, much time and cost would incur if all possible solutions are computed. So, some researchers would use the tabu search algorithm to solve and calculate the best combinations. First the researcher must set related parameters, including the permutations of the random initial solution, $X_0 = \{C_1, C_3, C_6, C_2, C_5, C_4, C_1\}$; current best solution $X^* = X_0$; highest number of computing iterations $K = 50$; cumulative number of times $k = 0$; and T_{length} of tabu list is 5. Now first iteration will be executed and use two random points in the neighborhood as 'move' and 'swap'. Assume that C_3 swapping with C_5 is the best solution of all possible moves, then the new order of sights would be $X_1 = \{C_1, C_5, C_6, C_2, C_3, C_4, C_1\}$. Next, we calculate the total distance generated in $F(X_1)$. If the best solution distance is greater than $F(X_1)$, then $X^* = X_1$ and $k = k+1$ and the order swap will be recorded into the tabu list (TL). This represents if there is a same random move swap in the future, there won't be another swap in order to avoid falling into local optimal solution. Of course, if the swapped order has been written into the exemption criteria, then such rule won't apply. After the first iteration is completed, the tabu search will check against the current TL list and exemption criteria and select the best proximal solution when X_{k+1}, then repeat the above formula and parameters until the stopping principle $K - k = 0$ where X^* will be exported as the optimal solution.

The shortest route planning in the research is based on the above formulas to undergo shortest route computation. Before using tabu search algorithm to arrange the shortest route, parameters must be defined that are illustrated in Table 4. First, there must be a first calculation of initial solution. In order to conform to the home care route planning, every nurse must plan in time order for the itinerary of the day. Formula 8 is: let the initial solution be the set S_{init}, in which H_{ie} and $L_{hospital}$ are the current position of the nurse and the position of the hospital to which the nurse will finally return. The median value in the set is the first-in first-out order of the visiting time of the day.

$$S_{init} = \{H_{il}, H_{ie} H_{i(e+1)}, H_{i(e+2)}, \ldots, H_{i(e+n)}, L_{hospital}\}. \quad \textbf{(8)}$$

2.3.3.1 Parameters of Our Tabu Search Algorithm

The definitions and description of related parameters of our tabu search algorithm are listed in Table 4.

Table 4. Definitions related parameters of tabu search algorithm

Item	Symbol	Description
1	S_{init}	Order of initialized set
2	S_{list}	Tabu list
3	$S_{list-length}$	Largest input length in tabu list
4	H_{ie}	Position of case 'e' on the daily schedule of nurse 'i'
5	H_{il}	The current position 'l' of nurse 'i'
6	$L_{hospital}$	The position of the hospital to which the nurse will finally return
7	a	Number of iterations
8	a_{max}	Maximum number of iterations

9	X_a	The solution X of the a_{th} iteration, normally known as the current solution
10	X^*	The optimal solution of the current algorithm
11	$F(X)$	Objective function of X

2.3.3.2 Flow Chart of Our Tabu Search Algorithm

The flow of tabu search algorithm for searching for the shortest route combinations is illustrated in Figure 4 and Algorithm 1. First, the visit location in the current itinerary must be the initial solution of S_{init}, and initialize the iteration setting from the first time to the stopping condition to be maximum of 30, plus set the current optimal solution X^* to equal to S_{init} and the length of the tabu list (Step 1 to Step 2). When the initial solution S_{init} is completed, the second step is to do proximal solution move-swap where the feasible solution of H_{ie} to $H_{i(e+n)}$ double location swap is added to the move step (Step 4 to Step 6). Then the best solution is selected from all the candidate moves to produce the best current solution of the first iteration X_1. In addition, in order to prevent repeat search, the swap move will be recorded in the first-in first-out method in the tabu list, S_{list}. In the third step begins the calculating the total distance of $F(X_1)$, evaluating and comparing to see if $F(X_1)$ is smaller than $F(X^*)$. The best or optimal solution will be refreshed and stored in X^* (Step 7 to Step 8). The last and the fourth step is checking the stopping principle to see if the current the number of iterations is greater than the maximum number set, and if not, that will be continuously executed until reaching the stopping principle and the best X^* solution is exported (Step 10 to Step 21).

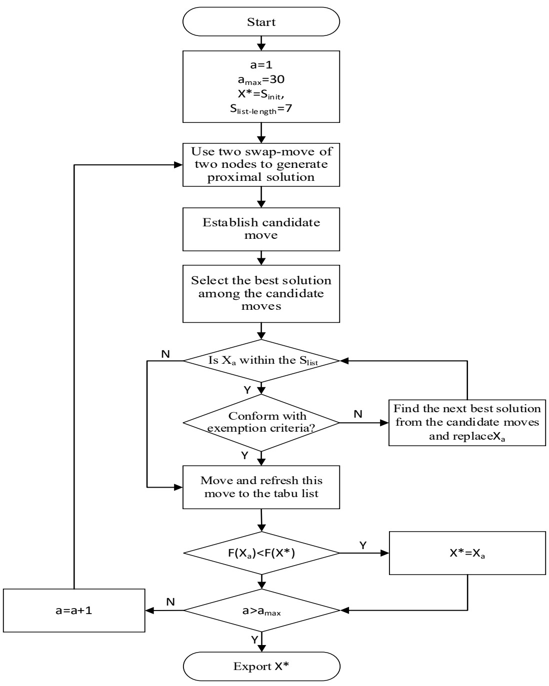

Figure 4. Flow chart of shortest route search algorithm

Algorithm 1. Our Tabu search algorithm

1: Input: $a \leftarrow 1, a_{max} \leftarrow 30, X^* \leftarrow S_{init},$
$S_{list-length} \leftarrow 7,$
$S_{list} \leftarrow [\ ], X_a \leftarrow 0,$
$H_{i(e,l)} \leftarrow Case\ "e,l"\ on\ schedule\ of\ nurse\ i$
2: Initialize the a, X^*, S_{list}, X_a
3: **for** iteration $a = 1, 2, ..., a_{max}$ **do**
4: Use two swap-move of $H_{i(e,l)}$ and $H_{i(e+n,l+n)}$.
5: Establish candidate move of $H_{i(e,l)}$ to $H_{i(e+n,l+n)}$.
6: Select the best X_a among the $H_{i(e,l)}$ and $H_{i(e+n,l+n)}$.
if $a <= a_{max}$ **then**
7: **if** $F(X_a) < F(X^*)$ **then**
8: $X^* = X_a$
9: **else**
10: **if** X_a within the S_{list} **then**
11: **if** S_{list} contain exemption criteria **then**
12: Move and refresh this move to the S_{list}
13: **else**
14: Find next solution X_{a+1} with $H_{i+1(e,l)}$ and $H_{i+1(e+n,l+n)}$
15: **return** Step 10.
16: **end if**
17: **else**
18: Move and refresh this move to the S_{list}
19: **end if**
20: **end if**
21: **end if**
22: **end for**
23: Output: X^*

3 Implementation of a Medical Grade Nursing Information System

A good home nursing care effectively interface hospital or organize medical information and assist nursing personnel to achieve the service goal of home care under wireless mobile mode. In this section, we introduce the construction of a medical grade nursing information system - a customized medical treatment care platform based on the methodology mentioned above.

A. Case receiving -distributing

The head nurse must distribute the new patient to the visiting list of the home care nurse when receiving a new case. As illustrated in Figure 5, all the head nurse has to do is enter the patient's information and pick the nurse's employment number to whom the case will be assigned. However, the head nurse must pay attention to the many limiting conditions such as whether the number of visits of the assigned nurse has exceeded 100 in the last month or the current month.

B. Pre-visit-itinerary planning

The home care nurse can schedule visit time for the day/ week/ month. As illustrated in Figure 6, the nurse only needs to click the left button of the mouse on the date of visit and an 'add event' window will appear. The nurse can select (the system will bring out the name of the patient of unfinished case) and enter relevant information (headline, begin time and end time, the material of the tube, whether to schedule the next visit, and note column) so the system will generate corresponding event and replace the manual schedule planning in the past.

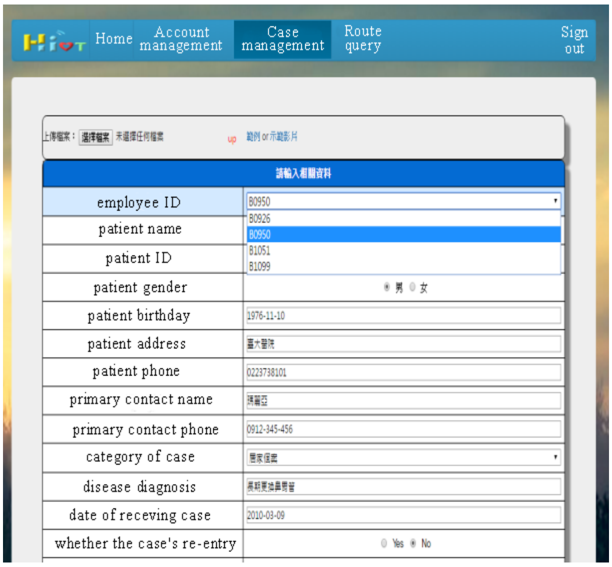

Figure 5. The head nurse distributing new case - system illustration

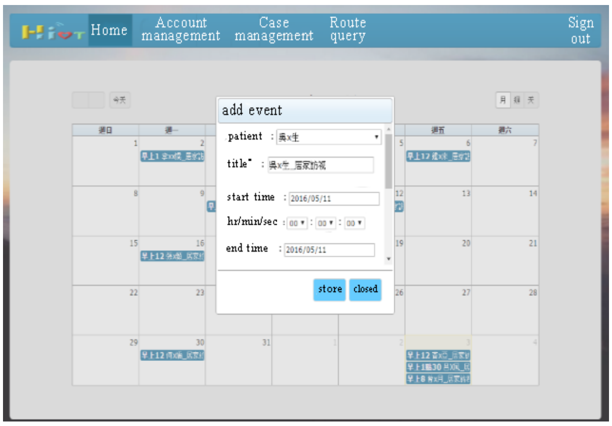

Figure 6. Electronic calendar and create new visit functions illustration

C. Pre-visit-the location of the case

The system will extract from the platform's database the address of the case based on the nurse's schedule of the day. The locations will be displayed as coordinate on Google Map in the form of an elderly figure on the screen of the nurse's handheld computer (as in Figure 7). The names and addresses of the case will also be displayed so the nurse will have a clear view of the locations for the day immediately.

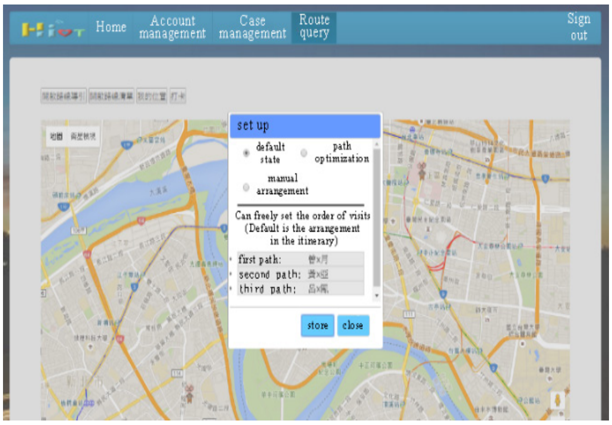

Figure 7. Illustration of the flexible real-time routing

D. During visit- positioning service and route planning mode

The system combines Google Map and GPS API of W3C for positioning function. The nurse only needs to open the webpage with the cell phone or tablet, the system will display dynamically the current location of the nurse on the map based on the GPS's positioning accuracy (precision) and certain calculation formula (the difference of the current distance and the previous distance) and store the relevant information into the database in order to facilitate the head nurse to coordinate and dispatch temporary support in an emergency situation.

In terms of visiting routes, the home care nurse only needs to click on the 'turn on route guide' button, and the system will automatically arrange the itinerary of the day in order plus the addresses will be imported and display as longitude-latitude values on the Map. The information includes timeline first-in first-out, emergency event, and the shortest distance which will be explained in detail in the following. Calculation of the shortest path is shown in Figure 8. A home care nurse needs to perform home care services at point *A*, *B*, *C*, *D* and *E*. According to the shortest path method, this system recommends the path of which takes 1 hour and 13 minutes (7 min + 13 min + 14 min + 24 min + 15min) and the total distance is 5.6 kilometers. The shortest path can help nurses to save time and energy consumed on traveling.

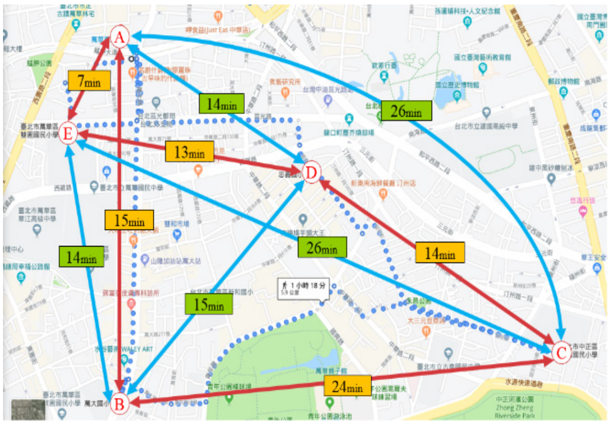

Figure 8. Demonstration of the calculation of the shortest path

4 Conclusion

The research constructed a cross-platform home nursing care cloud system to help the home care nurses optimize before, during, and after-visit work. The research designed a front-end platform based on actual demand to replace the manual 'pen and paper' calendar/schedule planning as in the past, and employed functions like Google Map to graphically present the visit routes of the day, positioning service, check-in mechanism, and case management to enhance the practicality of the system, reduce human errors of mis-recording, and ensure and stabilize the best nursing care quality. Moreover, in order to facilitate the head nurse to supervise and assist, the system also designed authorization management and tracking positioning functions to that the head nurse can quickly execute regional arrangement and temporary dispatch in an emergency situation (such as loosening or falling off of the tube). The functions not only help the patient resolve a dangerous incident but also preclude the anxiety of the family members. The contributions of the research include:

1. Through actual and clinical home care by the nurse, the current manual itinerary calendar schedule planning and the limiting conditions are built into the system so that the home care nurse can quickly set the time for the next visit, reduce human error in mis-recording that leads to mishaps and workload outside of the care service.

2. Positioning and check-in functions by combining Google Map v3 API and W3C Geolocation API record the current position of each nurse in the home of the patient. The check-in function will ensure that the home care nurse will duly execute visits planned by the system and help with supervision and management of the out-of-hospital home care.

3. Based on the flow of visitation, the system helped the nurse to quickly grasp the routes planned for the day. With algorithm, three modes of schedule planning, shortest route, micro-adjustment, and timeline, can assist the home care nurse to operate the system intuitively and display in the Map to increase the mobility of the caring personnel and reduce the time for look-up and arrangement and even lower the transportation cost of the home care department.

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