An Intelligent Service Planning System for Effective Home Care Service Scheduling

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Abstract—**Due to the increasing aging population over the world, it is challenging to take care of the large number of elderly people who are weak and living alone. In order to assist them to remain part of the community, home care services are being focused on enabling elderly people to receive nursing and care services in their familiar home and community environment. However, with the increasing need for home nursing care services, there is an insufficient number of nursing staff to provide service to these elderly people. Further, nursing staff may need to work on tight schedules to fulfill the extra needs of the elderly, and may affect their working performance and result in poor service satisfaction. In this paper, an intelligent service planning system (ISPS) is designed for facilitating decision making in effective home care service scheduling. The Genetic Algorithm (GA) approach is applied in the system to formulate the service schedule for each nursing staff by considering the estimated time for serving the elderly. In order to validate the feasibility of the proposed system, a case study was conducted in a healthcare center. The results show that the service satisfaction from the elderly and the work satisfaction of the nurses are both increased.**

I. INTRODUCTION

Aging has become a global problem faced by many countries. It is due to the improvement in medical treatment and in the quality of human life, leading to longer life-spans. Lutz et al. [1] measured the speed of population aging for the world as a whole, in 13 major regions such as Japan, China and Canada. They predicted that the median age of the world's population increased to 37.3 in 2050 from 26.6 in 2000. In other words, the median age of the world's population will increase by nearly 10 over 50 years. The aging population leads to a greater spending of governments on medical support, as the needs of the medical service are greatly increased. Hong Kong also faces the same problem of an aging population. According to the Census and Statistics Department in Hong Kong, the projection of elderly population (aged above 65) will increase to 36% in mid-2064. The phenomenon of the aging population has a great impact on both society and the economy. With the increase in the elderly and chronically ill patients in Hong Kong, the need for long term healthcare treatment is rapidly increasing and hence significantly increases the pressure on healthcare service providers.

To enable the elderly enjoy a better quality of life, the concept of "ageing in place" and "continuum of care" was emerged to allow the elderly to continue living in the community by providing home care services to them. Home care service is the care provided by licensed healthcare professionals at home. The services include medical treatment needs and daily assistance to the elderly for their daily living activities. However, due to increasing need for home nursing care services and the high turnover rate of home nursing staff, there is an insufficient number of nursing staff to provide such service to the elderly [2]. According to Donoghue [3], nursing staff usually have to work in tight working conditions as they have to travel to different service locations every day. Their work satisfaction is found to be low which leads to a high turnover rate of nursing staff. Without a systematic approach to effectively arrange the schedule of nursing staff, it is difficult to fulfil the increasing demand for home nursing care services, while the service satisfaction from the elderly and the work satisfaction of the nursing staff can be improved. Therefore, in this paper, an Intelligent Service Planning System (ISPS) is proposed to facilitate the decision making of effective home care service scheduling. GA is applied to reduce the overtime working of home nursing staff in order to improve the service quality, and, to maximize the number of elderly that can be served in home nursing care services.

The remainder of this paper is organized as follows. Section II reviews the past literature regarding home health care services, service scheduling in the healthcare industry, and genetic algorithm-based service planning. Section III presents the architecture of the proposed ISPS. Section IV describes a case study in a home health care services provider to validate the feasibility of the proposed system. Section V discusses the results and advantages of adopting the ISPS. Section VI gives the conclusions.

II. LITERATURE REVIEW

A. Home Health Care Services

The need for home nursing care is increasing in recent years due to ageing population. Most of the elderly tends to live at home and join social activities in the community as long as they can manage their daily living by themselves. Compared to the elderly living in nursing homes, the elderly receiving home care nursing service are less functionally impaired and usually have the ability to live independently with minimum caring support [4]. In order to maintain their quality of life, providing appropriate home nursing care service is essential for elderly who are weak or suffering from chronic diseases. Since home nursing care service aims at providing basic medical care and daily support to the elderly so that they can living in their own homes, it is a long term service which has high workforce demand in the industry. Home nursing care staff have to provide outreach service by visiting the elderly at their home, frequently and regularly. However, efficient workforce management is difficult to achieve due to high unpredictable demand and high operation costs [5]. Home nursing care staff usually have a tight

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schedule every day and have to work overtime so as to fulfill the increasing demand of the elderly. Irregular working hours, high workload pressure and lack of management support leads to nursing staff dissatisfaction in providing home care services [6][7]. Hence, having an effective service schedule is crucial to enable a stable workforce for home care services [8].

B. *Service Scheduling in Healthcare Industry*

An effective home health care routing and scheduling plan provides a daily schedule by assigning suitable nursing staff to the elderly so as to maintain high resource utilization and a satisfactory service level of home care services. The service scheduling plan mainly focuses on providing home care activities such as cleaning, laundry assistance and preparing food at the home of elderly by the outreach nursing staff [9]. In order to reduce the turnover rate of the nursing staff and increase their work satisfaction, Ernst and Krishnamooethy [10] suggested that better scheduling and rostering can help to increase the effectiveness of the staff and even improve the work performance. To increase the work satisfaction of nursing staff, workload balancing is considered as one of the key factors when formulating a service schedule [11]. Lanzarone and Matta [12] focused on balancing the workload assigned to nursing staff under care continuity in order to avoid process inefficiencies, treatment delays, and low quality of service. Cheng and Rich [13] proposed to minimize the number of hours of overtime and part-time work of residential healthcare for both full-time and part-time healthcare personnel. Benzarti [14] discussed the tradeoff between balancing the nursing care workload and minimizing the travel distance to the home of the patient. Apart from workload balancing, Mankowska et al. [15] suggested that the individual service requirements of the elderly, qualifications of staff and possible interdependencies between different service operations should be taken into consideration when formulating a home health care routing and scheduling plan. Trautsamwieser and Hirsch [16] assigned nursing staff to the elderly by considering the work time regulations, hard time windows and mandatory breaks with the objective of minimizing the traveling time of the nursing staff and the dissatisfaction level of the elderly and nursing staff. From the above literature, it can be seen that major consideration in formulating an effective service scheduling and routing model is in the minimization of the nursing staff's travel distance, while considering their working time and the satisfaction of patient.

C. *Genetic Algorithm-based Service Planning*

The Genetic Algorithm (GA) technique provides a searching function based on the natural selection mechanism and natural genetics. The fundamental principle of GA is to mimic the success of natural evolution through random selection and the reproduction of offspring [17]. Research has suggested that GA is able to produce good-quality solutions for vehicle routing problem in terms of coverage of collection points by choosing suitable locations for the collection points [18]. Liu et al. [19] proposed a GA model to solve a vehicle routing problem with simultaneous delivery and pickup and time windows in home health care. Later, Sinthamrongruk et al. [20] applied GA to formulate the healthcare staff routing problem to achieve the minimum total cost. Due to the complexity found in formulating a home care service scheduling plan, GA is considered as a useful technique to determine the service route for providing daily basic caring and professional nursing services to the elderly.

In summary, the needs of knowledgeable nursing staff to provide home care services are increasing due to ageing population all over the world. By providing basic medical care and daily support, the elderly can continue to live in the community independently. With the goal of allowing more elderly to be served, an effective home health care routing and scheduling plan is essential. Therefore, this paper proposes a GA-based intelligent service planning system to formulate a service schedule for home care nursing staff. It is expected that both the service satisfaction from the elderly and the work satisfaction of the nurses are increased by considering the travel distance and workload of the nursing staff.

III. System Architecture of the Intelligent Service Planning System

In this section, an Intelligent Service Planning System (ISPS) is proposed to schedule nursing staff in delivering home nursing care services. Fig. 1 shows the architecture of ISPS, which consists of 3 modules. They are (i) data collection module, (ii) decision support module, and (iii) solution generating module.

A. *Data Collection Module*

In this module, feedback and comments are collected from the nursing staff and the elderly through interviews to investigate if there is a need for improvement in the current services. For instance, some nursing staff may think that the current schedules are too tight and it is too much of a rush to get to the next service location. On the other hand, the elderly would have concern on whether the nursing staff are spending enough time at their home and the service delivered is of good quality. Besides service performance, arriving at the patient's home on time is also important in the home care service. Any delay in providing the service may cause inconvenience such as disturbing the resting time of the elderly.

Furthermore, basic information, such as service locations, current routing routes, and number of nurses available every day, are also collected from the healthcare organization. The data collected are then preprocessed. The purpose of data preprocessing are data purifying, data integration, and data reduction. For instance, data, which are incomplete, or inconsistent, are removed in the data processing. Data in different formats are transformed to standardized format and stored in the database. Useful data are then extracted and presented in a suitable form in the system.

B. *Decision Support Module*

Relevant data from the data collection module are extracted and transferred to the second module, the decision support module, for constructing the mathematical model to solve the identified problems. The data includes the set of locations, the set of staff members, the service time in each location, and the travelling time. The mathematical model for nursing staff scheduling is formulated in this part. Table 1 shows the notation of model. The objective function of the model in (1) is to

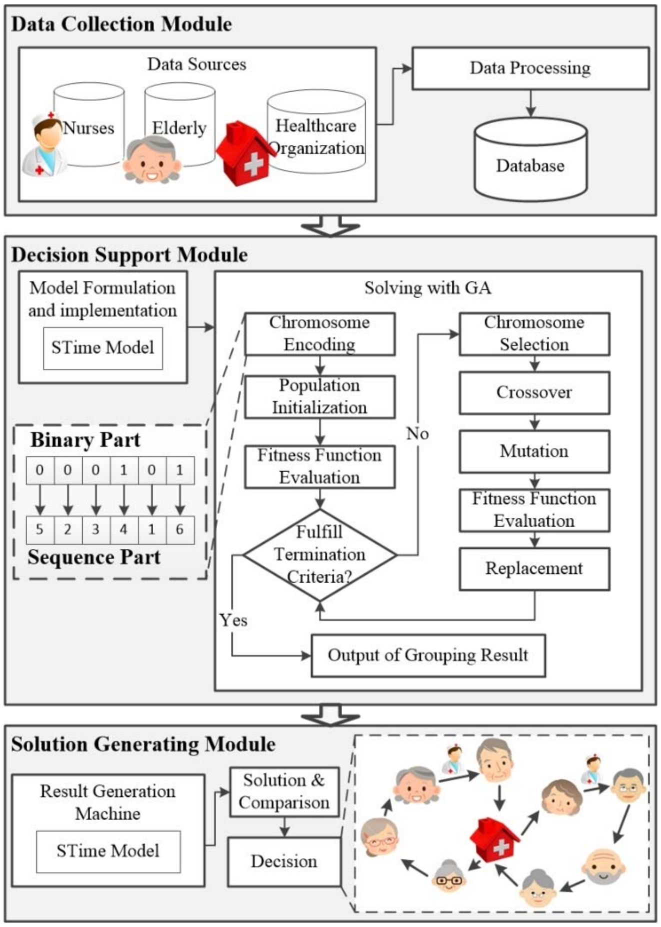

Fig. 1. System Architecture of ISPS

minimize the total time T, where T is the sum of the total service time and the total travelling time. Constraint (2) ensures that all patients are served exactly once. Constraint (3) ensures that the routes are taken by the same nurse at a particular location. Constraint (4) defines the minimum and maximum working time of each staff. Constraint (5) limits the total service time for each patient. Constraint (6) prohibits a sub-tour in the whole system by creating an intermediate variable α_j. Constraint (7) defines α_j as a non-negative integer. Constraint (8) defines x_{ij}^{f} as a binary variable.

TABLE I. NOTATION TABLE

Notation	Definition
Sets	
C_0	Set of all nodes of n elderly locations and 1 depot, $U\ \{0\}$
F	Set of all staff members
Parameters	
W_{max}	Maximum daily total working time
W_{min}	Minimum daily total working time
U_t	Time limit for providing service for each elderly
t_i^s	Service time at elderly location i
t_{ij}^t	Travelling time from location i to j
Decision Variables	
X_{ij}^f	Binary variable when staff $f \in F$ serve the elderly j, from location i to j (arrive), and from location j to k (leave)
α_j	Intermediate variable for prohibiting sub-tours; can be interpreted as position of node $j \in C$ in the route

Objective function

$$\text{Min } \sum_{(i,j)\in C_0} \sum_{f\in F} (t_i^s + t_{ij}^t)\, x_{ij}^f \quad (1)$$

Subject to

$$\sum_{(i,j)\in C_0} \sum_{f\in F} x_{ij}^f = 1 \quad (2)$$

$$\sum_{i\in C_0} x_{ik}^f - \sum_{j\in C_0} x_{kj}^f = 0, \forall k \in C_0, i \neq j \quad (3)$$

$$W_{min} \leq \sum_{(i,j)\in C_0} (t_i^s + t_{ij}^t)\, x_{ij}^f \leq W_{max} \quad (4)$$

$$t_t^s \leq U_t \quad (5)$$

$$\alpha_j \geq \alpha_i + 1 - n(1 - \sum_{f\in F} x_{ij}^f) \quad (6)$$

$$\alpha_j \geq 0 \quad (7)$$

$$x_{ij}^f \in \{0,1\} \quad (8)$$

After the formulation of the nursing staff scheduling model, GA is applied to determine the optimal solution with minimum travelling time and service time. Fig. 2 shows the encoded chromosome of the model. It shows a feasible solution and it helps to create different chromosome offspring for the generation. The length of the chromosome is decided by the number of nodes in the problem. The chromosome is divided into two parts, tour division region and route sequence region. In the tour division region, a binary number is used to denote whether a tour is finished, i.e. 0 indicates that the nursing staff continues the tour to another service location, 1 indicates that the nursing staff has finished the tour. In the route sequence region, real integer numbers are used to show the sequence of the service locations. As illustrated in Fig. 2, the first nursing staff will travel to locations 42, 11 and 13 respectively, while the second nursing staff will travel to locations 2 and 20 respectively. With the objective of minimizing the total service time and travelling time, the GA will undergo the process of crossover and mutation to generate a better solution. The process will stop when the termination criteria is met.

C. Solution Generating Module

In this module, Palisade Evolver is used to perform the GA calculations and a number of simulation experiments are conducted by applying different GA parameter settings. The total time of each route and the number of nurses required for serving the elderly can be determined with respect to the objective in minimizing the total time T. This can provide decision support for corresponding staff to setup an appropriate schedule for nursing staff based on the result generated. In order to obtain a better solution, it is required to compare the solution generated from different parameters settings of the GA before

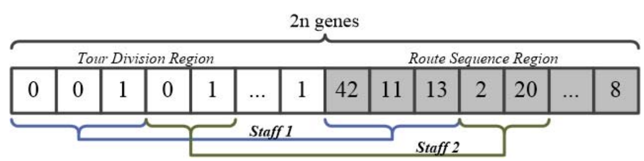

Fig. 2. Chromosome Encoding of the model

making a decision. The parameters include the population size, crossover rate, mutation rate, and the number of trials.

IV. Case Study

In order to validate the feasibility of the proposed system, a case study was conducted in the ABC Family Service Center in Hong Kong.

A. Company Background

ABC Family Service Center is a home care service center in Hong Kong, which was established in 1954. It is located in Kwun Tong and serves the elderly in Kwun Tong, Lam Tin, and Kowloon Bay. It provides mainly two types of services, basic care and medical care, to the elderly. Basic care includes elderly personal care and basic housework. Medical care includes medicine delivery, caring treatment for the weak elderly, caring treatment for disabled, and recovery training.

There are a total 16 nursing staff, serving 90 patients in the region. 6 of them are full-time staff and 10 are part-time staff. Each nursing staff is required to work 9 hours per day, including a one-hour lunch time and several breaks (50 minutes in total per day) after each service delivery. Currently, it is found that the schedules of nursing staff are too tight to visit all the service locations. They always have to rush to different locations for providing home care services every day and sometimes have to work overtime to complete all the service orders. With tiredness, nursing staff may not perform well in the service locations. Thus, complaints have been received from the elderly and they are not very satisfied with the service performance.

B. Implementation Flow of ISPS in the ABC Family Service Center

In order to improve the service quality and performance, ISPS was implemented in the ABC Family Service Center to plan the nursing staff service schedule. Fig. 3 shows the implementation flow of ISPS. There are four main processes, which include data collection, data processing, development of the GA model, and data analysis. After the implementation process, the results can be generated.

Firstly, relevant data are collected from three data sources including nursing staff, the service center, and elderly. By conducting interviews with managerial staff and front-line nursing staff of ABC Family Service Center, feedback and opinions on the current working schedule were collected. The service requirements such as service locations, elderly personal data and their required services were also collected from the service center. The current daily working schedule was also collected to compare with the routes generated by the system. Besides, interviews were also conducted with the elderly to evaluate the current service performance and how the ISPS can help to improve the service. All collected data was then stored in the database for further process.

Based on the mathematical model discussed in the previous section, GA is applied to generate the home care service schedule, by minimizing the total travelling time and service time for all nursing staff. Fig. 4 shows the interface of GA model setting. To calculate the traveling time of nursing staff, the distance between each service locations is determined via Google Map. For the service time, it depends on the types of service required by the elderly. Currently, the ABC Family Service Center provides six types of services to the elderly: personal care, meal delivery, basic housework, weakness treatment, disabled treatment, and recovery training. The elderly can have more than one type of service during each visit. The standard time to perform the services and sample service requests are shown in Table II.

In order to generate a better result, different combinations of parameter settings, including the number of generations, crossover rate and mutation rate, are studied. Different numbers of generations may affect the accuracy of the simulation, however, a larger number of trials requires a longer computing time. In addition, to generate more combinations of chromosomes for an optimum solution, crossover and mutation are performed in the generation. Crossover is the process to exchange the chosen genes between the pair of chromosomes. In mutation, the gene value is changed to another value randomly. Table III shows the GA parameter settings. After

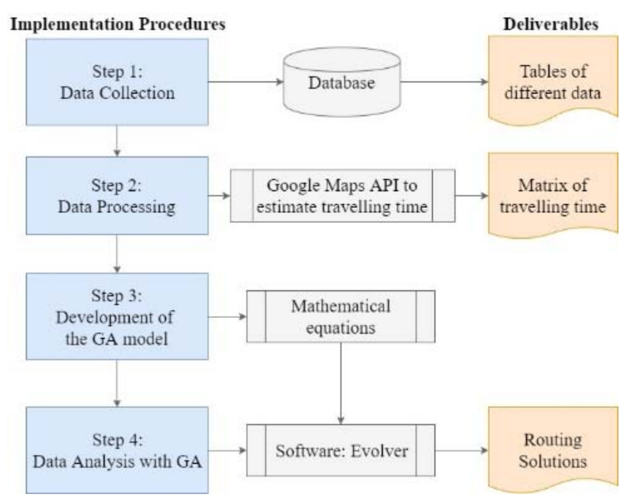

Fig. 3. Implementation Flow of ISPS

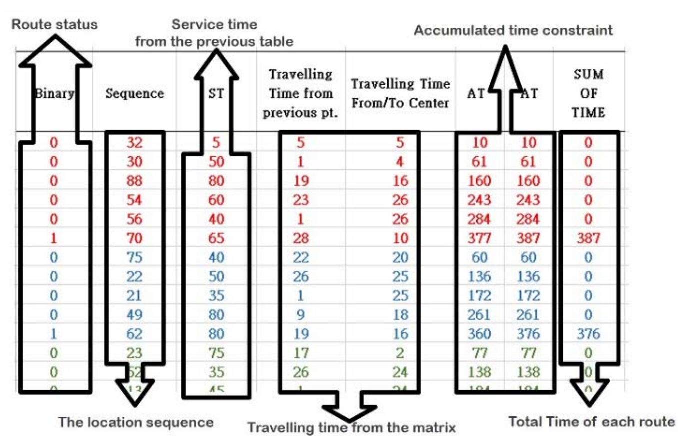

Fig. 4. Interface of GA Model Setting

TABLE II. STANDARD SERVICE TIME OF SIX TYPES OF SERVICES AND SAMPLE SERVICE REQUESTS

		Personal Care (15 mins)	Meal Delivery (5 mins)	Basic Housework (30 mins)	Treatment (Weak) (30 mins)	Treatment (Disabled) (35 mins)	Recovery Training (40 mins)	Total Time (mins)
1	Hing On House	√	√	√				50
2	Cheung On House		√	√	√			65
3	Sun On House	√	√	√		√		85
4	Block 15 Laguna				√			30
5	Block 34 Laguna					√		35
6	Block 21 Laguna						√	40
7	Ping Wong House	√	√	√				50
8	Ping Shun House	√			√			45
9	Tao Nga House					√		35
10	Kwong Yat House		√				√	45

getting the results with different settings, the settings with best performance are used to generate the finalized results.

After conducting a set of experiments, it is found that 15,000 generations with crossover rate 0.9, and mutation rate 0.05 provide a better solution among all the settings. Fig. 5 shows a sample route generated by GA. 14 nursing staff members are required in the day to fulfill the service requirements in all 90 locations. The total travelling time is 5353 minutes to complete all services.

V. RESULTS AND DISCUSSION

In order to validate the performance of the model, the service planning result before and after implementing the GA solution are compared. Before the implementation of ISPS, the service plan is generated manually, without considering the traveling time between each service locations. Nursing staff always have to work overtime due to long traveling times. After implementing the ISPS in the ABC Family Service Center, the nursing staff follow the generated schedule for providing caring services to the elderly. In general, the generated schedule is able to take into consideration the ideal traveling time, meal time and break time of the nursing staff, thus providing an effective solution in service planning. With the proposed ISPS, the service performance is improved and the staff satisfaction of working schedule increased.

A. Improvement in the Work Satisfaction of Nursing Staff

After the optimal routes are used, the nursing staff can have a more effective working schedule. They are spending less time in travelling so they can take a rest during their break time. In the past, since the schedule is tight and travelling time is long, their break time is actually spent on public transport. With the optimal routes, their working schedules are more effective.

TABLE III. GA PARAMTER SETTINGS

Parameters	Settings
Population size	50
Number of generations	8000/15000
Crossover rate	0.7/0.9
Mutation rate	0.05/0.1

Therefore, nursing staff can plan their meal time and break time effectively. Based on the survey done before and after implementing ISPS, the satisfaction scores of nursing staff increased from 5.5 to 8.2. This flexibility increases the staff loyalty towards the service center. To consider staying in a company or not, a staff member is not only thinking about salary and the job nature, but also the level of freedom they can enjoy. By making the schedule less tight and allowing more free time, nursing staff loyalty towards the service center would increase and they would tend to continue their work in the ABC Family Service Center.

B. Improvement in Service Satisfaction of Elderly

As nursing staff now have an effective schedule, they can spend more service time in the service location. They are not rushed during the service. The service quality is improved and the elderly are highly satisfied with the service performance now. Moreover, with more time available for each visit, it allows the nursing staff to communicate with the elderly. This improves the mental health of the elderly as well. As most elderly are living alone, developing a good relationship between the nursing staff and the elderly can help to understand the elderly behavior

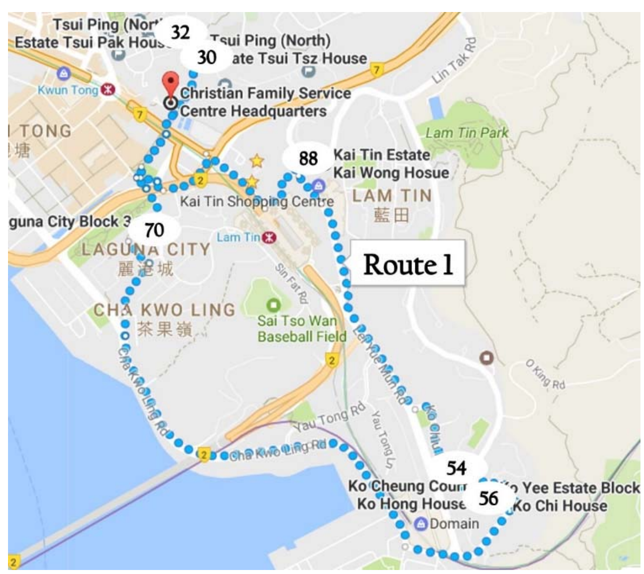

Fig. 5. Route Generated by GA

so that the service center can provide corresponding support to them. After the implementation of the ISPS, it is found that the satisfaction score increased from 7 to 8.9 on average, which means they are more satisfied with the service.

C. Solution of Insuffient Nursing Staff in the Center

The requirement for nursing staff fluctuated before the implementation of ISPS. The range was 15 – 19 nurses, and the service center had to recruit more part-time nursing staff to complete all the service requirements. After the ISPS was implemented, the arrangement of the nurses becomes stable, requiring 14 – 15 nursing staff per day. Besides, the workload of every nursing staff is balanced to reduce the chance of working overtime due to insufficient nursing staff.

VI. Conclusions

Home health care services have become of increasing concern in supporting the quality of life if the elderly. With appropriate healthcare support from the society, they are able to stay and receive medical care and daily support in the community. However, with increasing demand, it is found that there is an insufficient number of home care nursing staff for serving the elderly and a lack of a systematic approach to schedule the routing for nursing staff. The tight schedule assigned to nursing staff may cause poor working performance and result in poor service satisfaction. With the use of GA in ISPS, an optimal solution for scheduling home care nursing staff is generated by considering the total travelling time, the working time of the home care nursing staff and the service requirement of the elderly. It also balances the workload of the home care nursing staff and reduces the need for overtime working. By adopting the ISPS in the Hong Kong-based ABC Family Service Center, the results shows that the service satisfaction from the elderly and the work satisfaction of the nurses are both increased. The significance of this paper is in providing a systematic approach for nurse scheduling and solving the problem of insufficient staff members to fulfill the increasing elderly home care service demand. However, it should be noted that the traveling time in this study is estimated based on the distance between two locations under good traffic conditions. Since the model is applied in real-life situations, sometimes nursing staff have to make slightly adjustments on the service schedule due to traffic congestion. Further work will be conducted to design a dynamic solution to adjust the service schedule by considering the real time traffic conditions and the updated work situation of nursing staff.

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