An Adaptive Clinical Decision Support System for Serving the Elderly with Chronic Diseases in Healthcare Industry

Valerie Tang[1], Paul K.Y. Siu[1], K.L. Choy[1*], H.Y. Lam[1], G.T.S. Ho[2], Carman K.M. Lee[1], Y.P. Tsang[1]

[1]Department of Industrial and Systems Engineering, The Hong Kong Polytechnic University, Hung Hom, Hong Kong

[2]Department of Supply Chain and Information Management, Hang Seng Management College, Shatin, Hong Kong

Abstract

With the increasing aging population worldwide, providing effective nursing care planning in nursing homes is important in meeting the expectations of elderly patients and in streamlining the healthcare information process, hence maintaining high quality services. Instead of the traditional manual nursing care planning formulation based on expert experience and subjective judgement, this paper describes an adaptive decision support system, namely the cloud-based nursing care planning system (C-NCPS), to enable decision making in formulating nursing care strategies. By integrating cloud computing technology and the case-based reasoning (CBR) technique, medical records and documents pertaining to the elderly can be captured in real time, while appropriate treatment plans based on past similar treatment records can be formulated. However, the current case adaptation processes in CBR rely on domain experts to modify retrieved cases which may not satisfy the needs of the elderly. Therefore, text mining is integrated in the case adaptation process of CBR for extracting up-to-date medical information from the Internet so that its efficiency can be improved. By conducting a pilot study in a nursing home, it was shown that the time for formulating applicable treatment plans for elderly patients can be reduced, and the service satisfaction level can be enhanced.

Keywords: nursing care plan formulation, cloud computing technology, case-based reasoning technique, text mining

1. Introduction

To cope with the global aging population, often with chronic illnesses, the provision of community-based long term care is demanding, and needs to be addressed immediately in modern society. Community-based long term care service providers are required to have better management in manpower, daily operation processes and assets in order to provide sufficient support for maintaining the health of the elderly. Since elderly patients who suffer from various chronic non-communicable diseases face difficulties in their daily life, such as moving around, feeding and taking medicine, inadequate healthcare support may worsen their health condition and even result in fatalities. In addition, due to their own lack of sufficient time and medical knowledge, families tend to place their parents in nursing homes so that they can enjoy a better quality of life.

The nursing home, one of the community-based long term care service centres, provides

residential care, meals, personal care and nursing care for the elderly with poor mental or physical disabilities (McCall, 2001; Munyisia, 2011; Zimmerman et al., 2014). In order to provide a comfortable living environment in nursing homes, during the admission process, a comprehensive evaluation of their historical health record and doctors' advice is essential to formulate an effective and customized nursing care plan. In usual practice, after accepting the admission application, admission staff have to communicate with the elderly and their families so as to understand their needs (Fleischer et al., 2009; Williams, Ilten & Bower., 2016). They then have to evaluate a large amount of collected information provided by doctors, such as body check records, in-patient medical records and blood test results, in order to formulate an appropriate nursing care plan.

However, there are two problems in the existing nursing care plan formulation process, as shown in Figure 1. Firstly, the current evaluation process relies on the experience and subjective judgment of the admission staff. This may increase the processing time for formulating the preliminary nursing care plan. In addition, after formulating the preliminary nursing care plan, admission staff have to evaluate its effectiveness through health status monitoring and feedback collection. During the implementation of the nursing care plan, human errors may be found in the manual decision making process and hence admission staff have to revise the plan frequently. The continuous revision process may result in low service satisfaction and loss of confidence in the treatment from the elderly (Johansson et al., 2002). Although a number of research studies have focused on the adoption of decision support systems in medical diagnosis and perception, little attention has been paid to increasing the efficiency and reliability of the decision making process in providing daily healthcare service to the elderly in nursing homes. Therefore, how to design a decision support system using cloud computing and the CBR for solving the daily routine problems and realizing the proposed system in actual practice provide the motivation for this study.

In order to tackle these problems and maintain a high service quality, a cloud-based nursing care planning system (C-NCPS) is propsed, which is specific to the elderly, so as to facilitate decision making of the admission staff in providing daily healthcare services, such as basic supportive assistance and daily checking. In the system, case-based reasoning (CBR) is adopted to formulate an appropriate nursing care plan by retrieving past nursing care records. On the other hand, text mining is used to extract updated medical information from the Internet so as to improve the quality of the nursing care plan. This paper is organized as follows: the literature related to current nursing care plan formulation approaches, cloud computing technology, artificial intelligence (AI) and text mining technique is reviewed in Section 2. Section 3 describes the architecture of the cloud-based nursing care planning system (C-NCPS) while Section 4 discusses a pilot study for implementing the proposed system in a nursing home. Section 5 presents the results and discussion of the proposed system. Section 6 gives the conclusions.

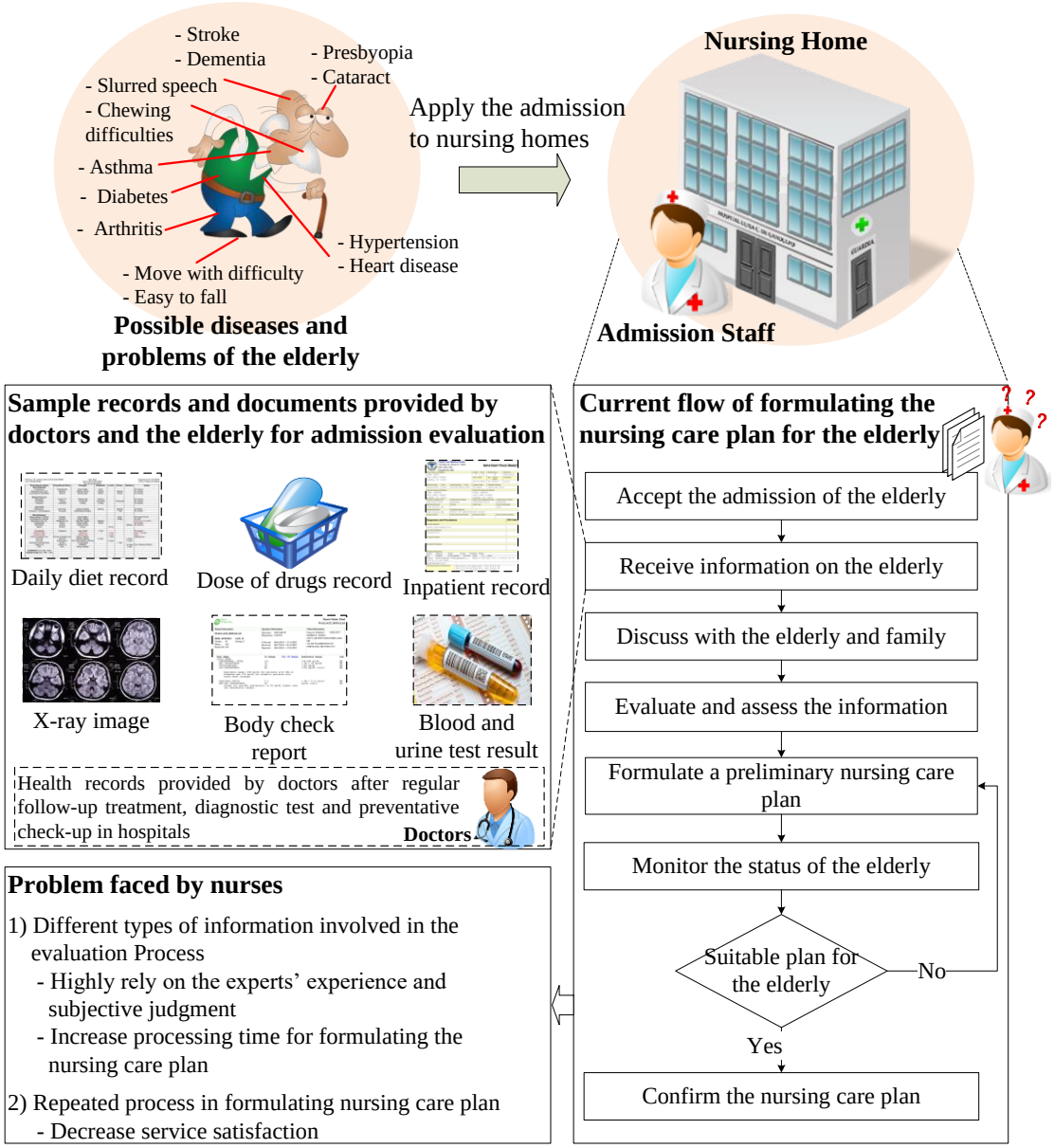

Figure 1. Existing problems in nursing care plan formulation process

2. Literature review

Supporting the aging population is a profound and pervasive challenge all over the world. According to the United Nations (2015), it is forecast that there will be over 2 billion persons aged 60 or over in 2050, more than double that in 2015. In response to facing the impact of the global aging population, long-term care has become important in handling the increasing demands of healthcare services in the community (Bloom et al., 2010). As one of long-term care service providers, the nursing home plays an important role in providing personal and nursing care to the elderly with chronic diseases and disabilities. In a nursing home, nursing care planning is a complex task for admission staff because they have to consider a huge amount of medical information for achieving the specific goals and strategies so as to meet the needs of patients (Chinman et al., 1999; Brandeau et al., 2004; McGuire et al., 2016). However, due to increasing concern about the quality of life of

the elderly, there is more emphasis on the quality of healthcare services they receive. The elderly and their families expect nursing homes to provide customized, innovative and updated care through appropriate nursing care planning. This forces nursing homes to continuously improve the quality of their healthcare services (Scott-Cawiezell et al., 2005; Kovach et al., 2008; Lee et al, 2015). Without any decision support system, the formulation of strategic nursing care planning becomes time-consuming and tediously iterative (Wang et al., 2007). It also increases the difficulty of sharing knowledge among admission staff for nursing care planning formulation. From the literature, it is found that researchers mainly focused on the study of the medical diagnosis and prescription. Chen et al. (2007) presented a model using a support vector machine to predict lung radiation-induced diseases. Bibault et al. (2016) suggested integrating big data and machine learning to develop a predictive model in radiation oncology. Researchers rarely paid attention to the possibility of increasing the efficiency and the reliability of the decision making process in providing daily healthcare services to the elderly in nursing homes. When considering the time to respond to the elderly and their families, it is important to develop a knowledge-based system making use of past records and explicit knowledge for facilitating the decision making in the nursing care plan and in delivering quality healthcare services to satisfy all their needs.

Case-based reasoning (CBR) is a knowledge-based and learning technique that facilitates decision making based on past experience (Kolodner, 1993; Aamodt & Plaza, 1994). It recalls and reuses knowledge and experience from previous cases to deal with a new problem (Pandey & Mishra, 2009; Prentzas & Hatzilygeroudis, 2016). Similar to human reasoning systems, the predictive process of CBR allows users to easily understand the results generated (El-Sappagh, 2015). Because of the advantages of CBR, in the last two decades, CBR has been successfully applied in the healthcare industry for designing systems for classification, planning, tutoring and diagnosis (Holt et al., 2005; Ping et al., 2015). Marling et al. (1999) used CBR to design a nutritional menu planning system using commonsense knowledge that met the nutrition requirements and constraints of different people. Wang et al. (2007) proposed a hybrid CBR approach to provide quality and accurate treatment planning for adolescent intervention in mental healthcare. Petrovic et al. (2016) developed a CBR system to generate new radiotherapy treatment planning for patients with brain tumors. However, currently, many researchers focus only on the case retrieval processes rather than case adaptation processes in CBR. This results in high uncertainties in the case adaptation processes due to the modification of retrieved cases that relies on the experience of domain experts (Reyes et al. 2015). The uncertainties may affect the analysis quality due to imprecision and conflicts in human decision making (Jabrouni et al., 2013). Moreover, Fuchs et al (2014) also argued that there is no generic model for case adaptation due to the difficulty in acquiring the necessary knowledge. In practical situations, a retrieved case without any modification is treated as the solution for the new problem. Since the elderly and their families expect to receive high quality healthcare services in nursing homes, they may not be satisfied with traditional healthcare services that cannot meet their requirements. Therefore, in order to acquire effectively updated healthcare information from the Internet, adoption of text mining techniques is a possible solution in the adaptation of case-based reasoning to reduce

uncertainties and meet the expectations of all the stakeholders.

On the Internet, there is a massive amount of medical information available for healthcare professionals, including doctors, admission staff and healthcare assistants to access. It is important for them to use the Internet to capture useful updates of medical information so as to improve service quality. Web mining, one of the text mining techniques, is able to effectively extract desirable knowledge from the Internet (Velásquez & Jain, 2010). It allows healthcare professionals to identify, manage and integrate knowledge from textural documents and hence discover hidden patterns and trends among the documents (Han et al., 2011; Romero et al., 2013). Typically, k-nearest neighbors, decision trees and the Naïve Bayes classifier are common web mining techniques for assisting decision making in the healthcare industry. Shouman et al. (2012) applied k-nearest neighbors to identify and analyze patients suffering from heart disease. Moon et al. (2012) proposed a decision tree model to characterize smoking patterns of older adults for enhancing the understanding of their health condition, distress level, demographics and alcohol use. However, due to the complex computation process and low speed of k-nearest neighbors and decision trees, the Naïve Bayes Classifier is able to discover valuable information in handling the huge datasets. Wang et al. (2003) developed a web document classification system using the Naïve Bayes Classifier to classify HTML documents. Leroy et al. (2008) adopted the Naïve Bayes Classifier to cluster online health information into three levels based on the inputted vocabulary, so as to increase the readability. Ting et al. (2013) proposed a Web Information Retrieval System, with the use of the Naïve Bayes Classifier, for physicians to efficiently and effectively retrieve web information. From the above literature, it is clear that web mining is a promising technique to improve the accuracy, efficiency and effectiveness in extracting useful knowledge from the Internet.

Furthermore, to provide a platform for improving communications between patients and admission staff, cloud computing is introduced to deliver computing services through the Internet to users (Huang et al, 2013; Stantchev et al., 2014). In the usual situation of stretched resources, including healthcare professionals, spending and community care, cloud computing provides a more innovative and cost-effective solution for healthcare providers in addressing the problem of the increasingly aging population (Sultan, 2014; Mital et al., 2015; Gupta et al., 2017). With electronic health records, cloud computing helps admission staff facilitate decision making in planning and budgeting (AbuKhousa et al., 2012). In addition, it improves the performance of healthcare organizations by better utilizing resources, securing medical records, delivering services and providing information that assists the decision making of various stakeholders and policies (Cegielski et al., 2012, Samuel et al., 2013). He et al. (2013) presented a private cloud platform to manage semi-structured and unstructured medical data so as to reduce the cost and improve the effectiveness in handling a wide range of healthcare services. Lin et al. (2014) proposed a cloud-based electronic health record system to enhance chronic disease management through the collecting of patients' health records in a rural region of China. IBM developed a cloud platform to collect and analyze patients' electronic health records and provided the relevant medical literature for enhancing the decision making of medical professionals. (Winters-Minter et al., 2015; Shader, 2016; Chen et al.,

2016). Zhang et al. (2017) designed a health system for multisource heterogeneous healthcare data storage and analysis using the cloud and big data analytics technologies. Therefore, cloud computing technology is a powerful tool to assist in the admission process and to enhance communication with admission staff in nursing homes.

In summary, current manual practice in nursing care plan formulation that relies on staff experience may lead to long processing time due to the large amount health information provided by the elderly that needs to be assessed. In addition, considering the high complexity in such formulation processes, human errors may be easily found in the manual decision making process and hence making revisions becomes a tedious iterative process. In view of the rising concern about the quality of life of the elderly, admission staff are not only required to provide efficient and effective nursing care plans, but should also obtain update healthcare knowledge to improve the quality of the nursing care plan. Therefore, a cloud-based nursing care planning system with the integration of cloud-based applications and CBR is developed to facilitate decision making in nursing homes. In addition, a novel approach that embeds the text mining in the case revision process in the CBR is proposed for nursing homes to formulate a more comprehensive nursing care plan process.

3. Design of the cloud-based nursing care planning system

In order to provide decision support to the admission staff, a cloud-based nursing care planning system(C-NCPS) is designed to formulate an effective nursing care plan. Figure 2 presents the system architecture of the C-NCPS, which consists of two modules: (i) front-end module and (ii) back-end module. The front end module is used to collect and store the personal information and medical records of the elderly using the cloud computing technology, and the back end module involves two engines: Case Retrieval Engine and Case Adaption Engine. The inductive indexing and nearest neighbor methods are involved in the first engine, the Case Retrieval Engine, for retrieving and ranking past nursing care records based on their similarity value. After that, the text mining technique is integrated in the Case Adaption Engine to enable searching for up-to-date health information in order to improve the quality of the nursing care plan. With the C-NCPS, the elderly and their families can upload the admission application form to the nursing home, while admission staff can capture new admissions in real-time and then effectively formulate an appropriate nursing care plan.

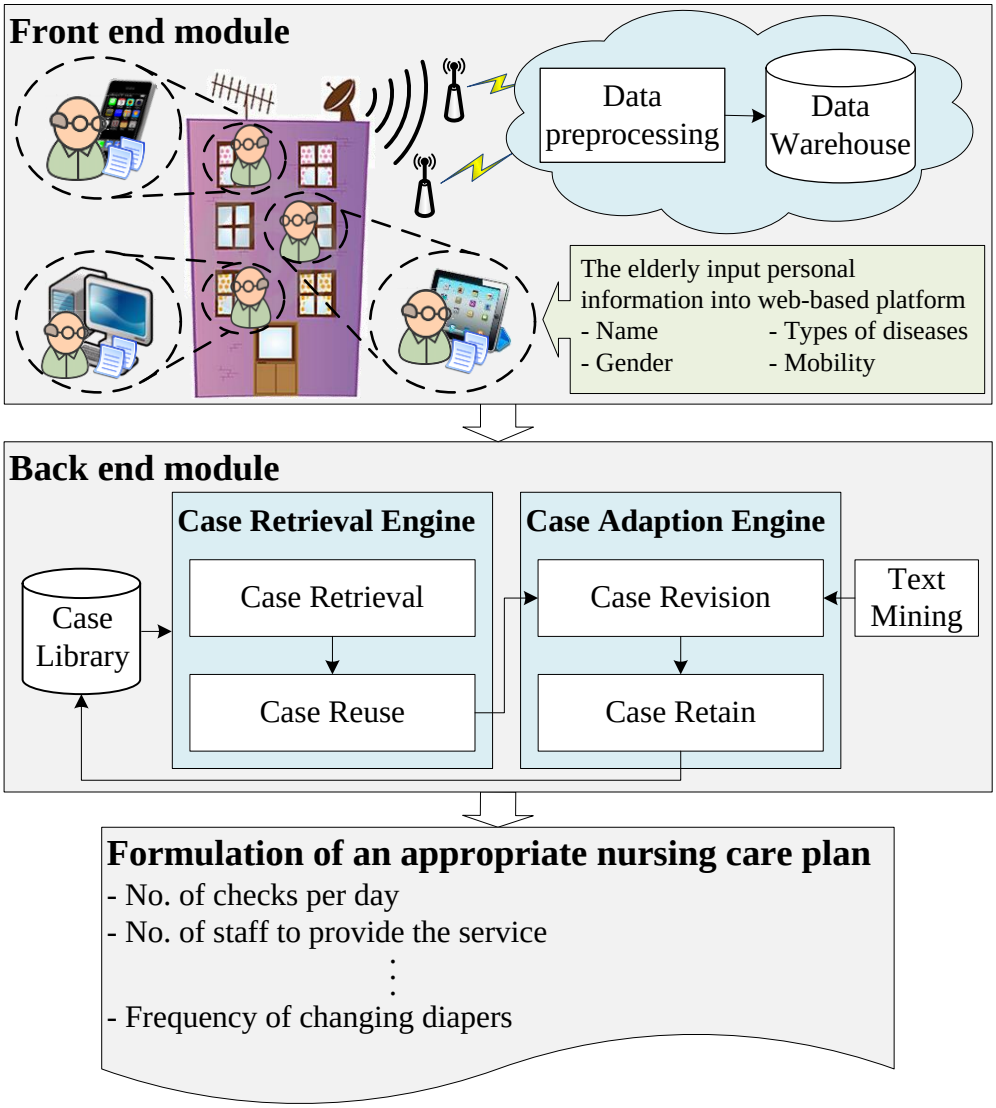

Figure 2. The architecture of the C-NCPS

3.1 Front End Module

When applying to a nursing home, an elderly patient, possibly with the family assistance, can go to the website of nursing home using various devices such as computers, smartphones and tablets for admission registration. In this process, they have to provide the necessary information including (i) personal information such as name, gender and address, and, (ii) medical records such as past body check records, inpatient records and disease records to the nursing home. With the use of the cloud-based platform, the elderly can submit this information online in the format of GIF, JPEG, MS WORD and PDF instead of applying for admission in person. This can increase the efficiency in applying for admission and provides convenience for patients who are living in remote areas. These data are then sent and uploaded to the cloud. In order to reduce any typo mistakes inputted by the elderly, rules and restrictions are created in the system. For example, only “Female” and “Male” are allowed for the selection of gender. In addition, considering incomplete and inconsistent data inputted by the elderly that may highly affect the quality of decision making in formulating care plan, data preprocessing is used to improve the data quality. Typically, there are four steps of data preprocessing, which are data

cleaning, data integration, data transformation and data reduction. If there are any missing values and inaccurate data found in the system, data cleaning can be used to detect and correct such errors so as to increase data consistently. In addition, medical records of the elderly may be provided by various healthcare parties and stored in different formats. At this point, data integration and data transformation are important for combining and consolidating the data into standard format for further processing. Finally, due to the large amount of medical information uploaded by the elderly, data reduction is adopted to minimize the data size and increase the data storage efficiency in the system. Apart from the information inputted by the patients and their families, the resources information and information for handling various illnesses and treatment methods are also inputted in the cloud-based data warehouse for facilitating the care plan formulation. Subsequently, useful data are stored in the cloud-based data warehouse which is connected to the C-NCPS. Authorized users, i.e. admission staff, can login onto the C-NCPS and real-time access information on a new applicant for further processing. Manual data verification is then conducted to check whether the inputted data match with the uploaded supportive documents. Once the nursing home accepts the admission application, admission staff will make direct contact with the elderly patient in order to better understand their needs.

3.2 Back End Module

In this module, relevant data stored in the cloud are transferred from the front end module for facilitating decision making by the admission staff. By evaluating the medical information and the requirements of the elderly, based on the past nursing care records, an appropriate high service quality nursing care plan can be formulated. Figure 3 shows the details structure of back end module.

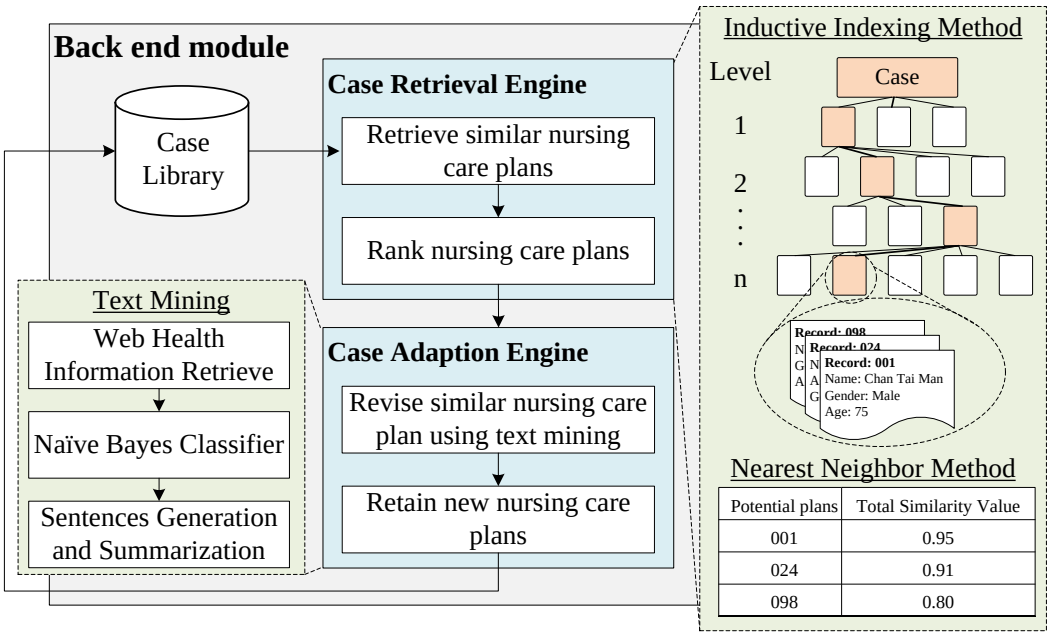

Figure 3. Detailed structure of the back end module

3.2.1 Case Retrieval Engine

In order to retrieve past nursing care records effectively, past records in the case library are stored and clustered according to the key attributes that are listed in the traditional application form and in

interviews with the admission staff. These key attributes include the health problems and personal information of the elderly, such as the degree of mobility, level of communication ability and self-care ability, all of which may influence health care decisions. For example, in treating patients who have difficulty in moving, the nursing home has to provide assistive devices such as crutches and wheel chairs. Apart from the health problems and personal information of the elderly, case record in the case library also contains the symptoms of diseases that help admission staff to identify and provide the daily healthcare services to the elderly. Based on the new data inputted by the elderly, admission staff are required to select the appropriate attributes in the C-NCPS for searching and browsing potential nursing care records from the case library. The inductive indexing method is applied to cluster the nursing care records according to the decision tree structure. Each tree level presents different health problems of the elderly. A group of potential nursing care records generated at the last level of the decision tree must contain the relevant attributes for formulating a new nursing care plan for the new applicants.

The potential nursing care records are then ranked using the nearest neighbor method to further analyze the suitability of the records. Through matching the corresponding attributes of the potential records, the similarity value of the new application to the elderly is calculated from Eq. (1) where W= $\{w_1, w_2, \ldots, w_n\}$ is a set of index of weighting for the attributes.

$$\frac{\sum_{i=1}^{n} w_{ri} \times sim(R_{old}, R_{new})}{\sum_{i=1}^{n} w_{ri}} \quad (1)$$

where w_{ri} is the weighting of the attributes defined by the admission staff and $sim(R_{old}, R_{new})$ is the similarity value between the new application and the potential nursing care records. By ranking the similarity value of the potential nursing care records in descending order, admission staff are able to select an important nursing care record, which is the record with the highest similarity value, as reference for generating the new nursing care plan. Subsequently, this record is transferred to the next engine, the Case Adaption Engine, for the revision process.

3.2.2 Case Adaption Engine

Although the use of the retrieved past records is suggested for admission staff to formulate a new nursing care plan, modifications are required to ensure the adaptability of the new nursing care plan. In addition, providing advanced caring methods in the revision stage is important to improve the service quality. Since there is a massive amount of healthcare information available on the Internet, the text mining technique is applied to increase the efficiency in extracting useful healthcare information. Figure 4 shows the mechanism of record revision using the text mining technique.

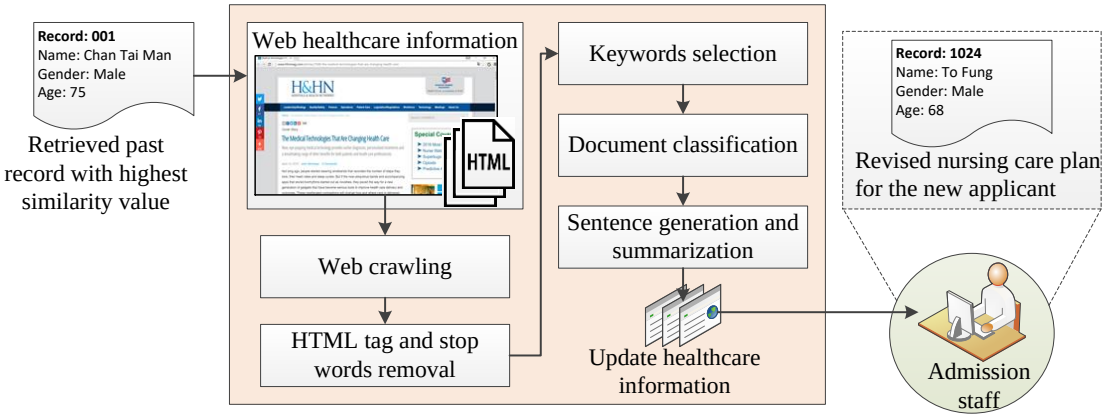

Figure 4. The mechanism of the record revision using the text mining technique

First, with the process of web crawling, useful information from the Internet is collected. In order to improve accuracy and reduce the noise in the retrieved information, tables and figures in the web pages are eliminated. In addition, HyperText Markup Language (HTML) tag and stop words, which are non-informative functional words, are also removed from the source code of the web page. Then, the function words with meaning are extracted and stored in a plain text file format.

Selection of keywords for document classification is the next step after generating the text file. In this step, the occurrence frequency and weighting of the terms and keywords in each document can be measured with the use of the Term Frequency-Inverse Document Frequency (TF-IDF) weight method. The retrieved documents are treated as weight vectors. The weight of each term in each document, w_a, is calculated based on Eq. (2).

$$w_{aij} = tf_{ij} \times idf_{ij} \quad (2)$$

where tf_{ij} is the occurrence frequency of term T_j in document D_i in which T_j is the term j in document D_i, and idf_{ij} is inverse of the frequency and the Eq. (3) shows the equation for idf_{ij}.

$$idf_{ij} = \log N - \log n_j \quad (3)$$

where N is the total number of documents and n_j is the number of documents that contain T_j. A result with a high term weight implies that the occurrence frequency of the term is high in the particular document and that the term only appears in a small numbers of documents. With the TF-IDF, the importance of the selected keywords can be extracted more accurately and comprehensively.

The Naïve Bayes Classifier is then adopted to classify the retrieved documents into various categories by calculating the probability of occurrence of keywords in a document. Features are independent of each other and contribute equally to the final decision making. The equation of the Naïve Bayes Classifier is shown in Eq. (4).

$$argmax\{P(C_k|d)\} = \frac{P(d|C_k) \times P(C_k)}{P(d)} \quad (4)$$

where $P(C_k)$ is the priori probability of the category, $P(d|C_k)$ is the conditional probability of generating d, given a fixed C_k and d is the particular document. However, the document may be classified into several categories with different probability values. In this situation, the document

belongs to the category with the highest probability value. With the use of the Naïve Bayes Classifier, the document can be effectively grouped with the correct category.

To further increase the efficiency for admission staff in reading the new healthcare document, the important sentences are extracted according to the score value of the sentences using the TF-IDF weight method. The formula for calculating the score value is given in Eq. (5).

$$s = \sum_{i=1}^{n} w_{ai} \quad (5)$$

where s is the sum of TF-IDF weights of an individual sentence. Through the combination of the sentences with higher score values, a short summary for the new document is generated for admission staff to revise the past nursing care record.

Once the new nursing care plan is formulated, details of the new record and revised report are sent and stored in the case library as reference for further use. With the increasing number of nursing care records in the case library, the C-NCPS can retrieve the nursing care records with higher quality and hence improve service satisfaction.

4. Case study

4.1 Company Background

In order to validate the performance of the C-NCPS, a case study was conducted in one of the largest private nursing homes in Taiwan, called the Comfort Nursing Home, involving formulating a nursing care plan for admission staff and healthcare assistants to follow. The aim of the Comfort Nursing Home is to provide comprehensive long term care service such as residential care, personal care and nursing care to elderly patients in order to improve their quality of life. Figure 5 shows the structure of the Comfort Nursing Home. With more than 100 staff, including doctors, nurses, healthcare assistants, social workers and cleaners, and a professional quality management system and adoption of advanced healthcare equipment, the Comfort Nursing Home intends to create a favorable and comfortable living environment for more than 200 residents. Because of the increasing concerns on patient satisfaction, the nursing home needs to better understand the elderly and their family needs, and hence provide an appropriate nursing care plan for them. Currently, the admission staff are responsible for handling the new admission applications based on their personal experience while healthcare assistants are responsible for executing the nursing care plan. It was found that that it is difficult for them to evaluate the application in a short period of time since the elderly submit numerous medical records such as blood test results and inpatient records. In addition, the nursing home has also received negative feedback from the elderly because of long evaluation time and repeated processing in formulating an appropriate nursing care plan. In order to tackle these problems and improve the service quality, the proposed C-NCPS was implemented in the Comfort Nursing Home for facilitating the decision making of staff. Considering involved the ethical issues in the research, the patients were required to sign a consent form for agreeing that their medical information can be used, and the identity of none of the patients was disclosed in this study.

Figure 5. Structure of Comfort Nursing Home

4.2 Implementation Flow of C-NCPS

Figure 6 presents the implementation flow of C-NCPS in the Comfort Nursing Home which consists of five steps: (i) design the content of online admission application, (ii) collect the relevant data through the cloud-based platform, (iii) retrieve and rank the potential nursing care records, (iv) revise the nursing care record by extracting the healthcare information from the Internet and (v) retain the new nursing care plan in the case library. Through converting the traditional admission method to the online platform, the information can be collected and stored in the data warehouse. Relevant information is used by admission staff to formulate the nursing care plan. In addition, useful healthcare information is extracted and taken into consideration in revising the past nursing care records.

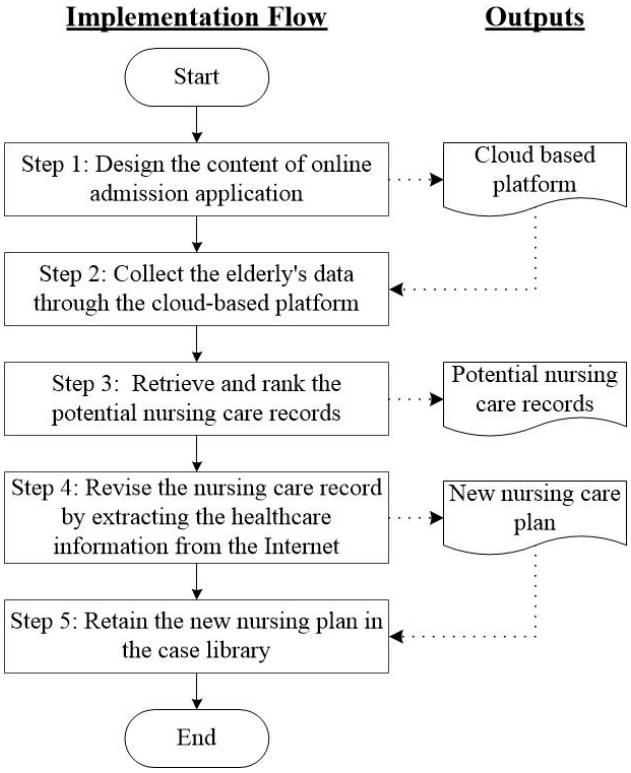

Figure 6. The implementation flow of C-NCPS

4.2.1 Design the Content of Online Admission Application

In this step, the online platform is established to replace the traditional admission application method, i.e. in-person application, in order to collect the information. It is important to distinguish which types of information are needed when applying to live in the Comfort Nursing Home. This information is also used by admission staff to determine whether the person is suitable to live in the home. Through the interview by the admission staff, it is found that (i) the application form, (ii) personal documents and (iii) proof of health documents are essential in applying for admission. First, an application form provides basic information such as the name, emergency contact and the types and severity of any diseases contracted. Second, personal documents refer to documents that can be used to identify the status of the new applicant such as identity card, proof of income and proof of address. Third, proof of health documents relates to documents that can verify the health status, including body check records, in patient records and test reports. Therefore, the cloud-based application platform is used for this information for formulating the nursing care plan. Figure 7 shows the conversion of the traditional application form to the online application. Apart from the information collected for establishing the application system, the admission staff are required to weigh the importance of the attributes in order to calculate the similarity values in selected nursing care records in Section 4.2.3.

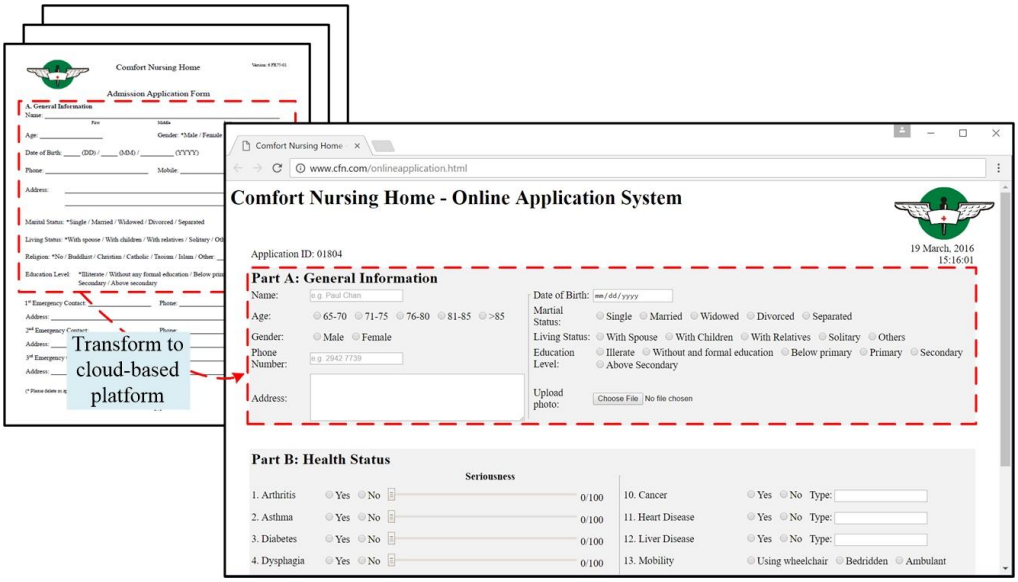

Figure 7. The conversion of traditional application to online application

4.2.2 Collection of Data through the Cloud-based Platform

With the cloud-based platform, the elderly and their families can enter the corresponding information for applying for admission to the Comfort Nursing Home. There are several parts in the application system, including the general information, health status, emergency contact, supplementary documents for proving the current health condition and any special requests. For the health status part, the elderly and their families are required to provide the diseases that they have had and the seriousness level, ranging from 1 to 100. At the same time, providing the health status documents is necessary for the admission staff to verify the information and prevent misuse of resources. The structure of the cloud data warehouse is shown in Figure 8. Data preprocessing is used for standardizing the submitted data and minimizing data errors before uploading the data to the cloud in the C-NCPS.

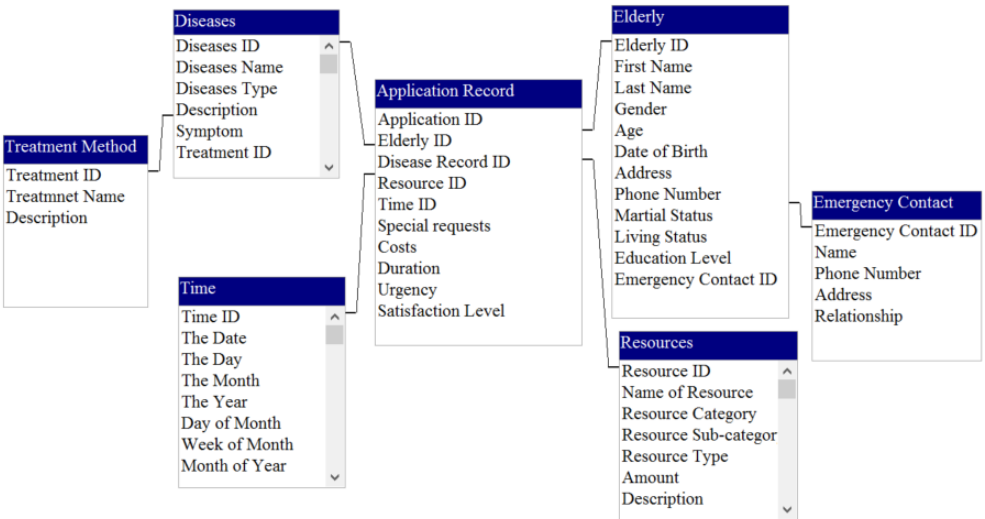

Figure 8. The structure of cloud data warehouse

4.2.3 Retrieve and Rank the Potential Nursing Care Records

After submitting the admission application, the admission staff can note the new application by logging into the C-NCPS. Figure 9 shows the flow of the back end module. In order to minimize any errors in the inputted data, the admission staff have to verify the accuracy of the data with the supporting documents. Figure 10 shows the user interface of C-NCPS for displaying a new application. In the C-NCPS, past nursing care records stored in the case library are retrieved through the inductive indexing method. Admission staff have to identify the key attributes which may significantly affect the formulation of a nursing care plan in constructing the decision tree and demonstrating the relationship within the selected nursing care records. Figure 11 presents the structure of the decision tree for the inductive indexing method. It consists of five levels: Level 1: Mobility, Level 2: Self-care ability, Level 3: Neuropsychiatric problem, Level 4: Communication ability and Level 5: Age. MySQL is adopted to develop the structure of the case library based on the five levels of the decision tree and the Application Case ID. A specific case set can be extracted using SQL programming, such as SELECT, INSERT, UPDATE and DELETE. According to the structure of the decision tree, past nursing care records in the case library are divided into different clusters. To retrieve the potential nursing care records from the case library, matching the specifications between the new application and past nursing care records is carried out along the search path of the decision tree. Only cases with the same attributes of the five levels of the decision tree to the new application are selected for case reuse processes.

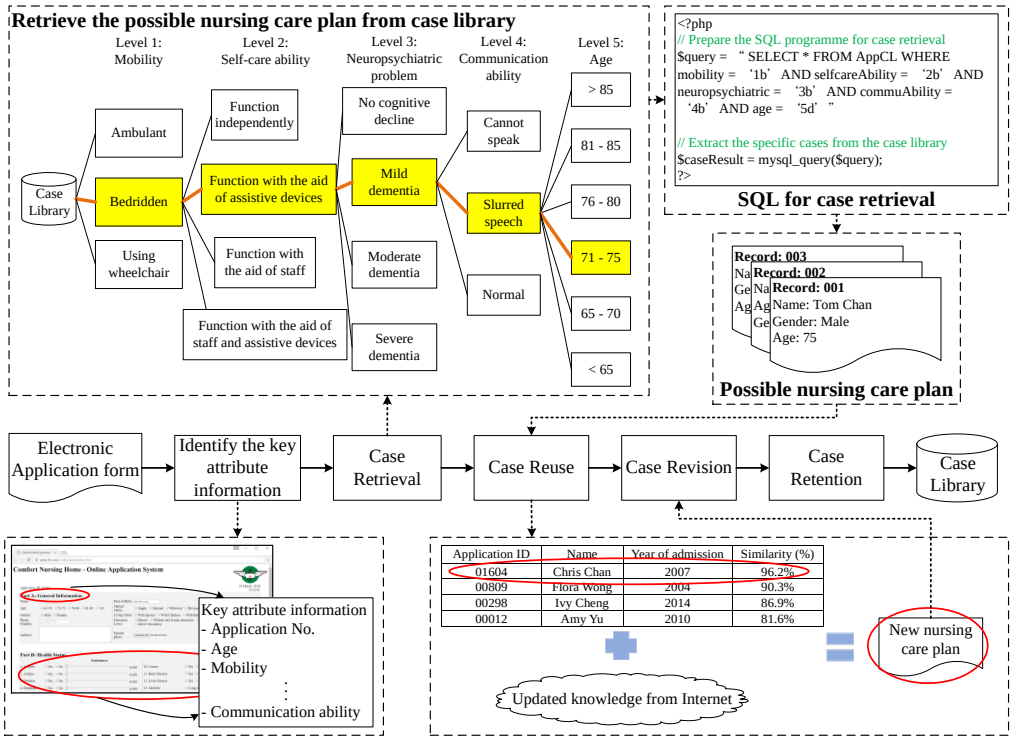

Figure 9. The flow of back end module

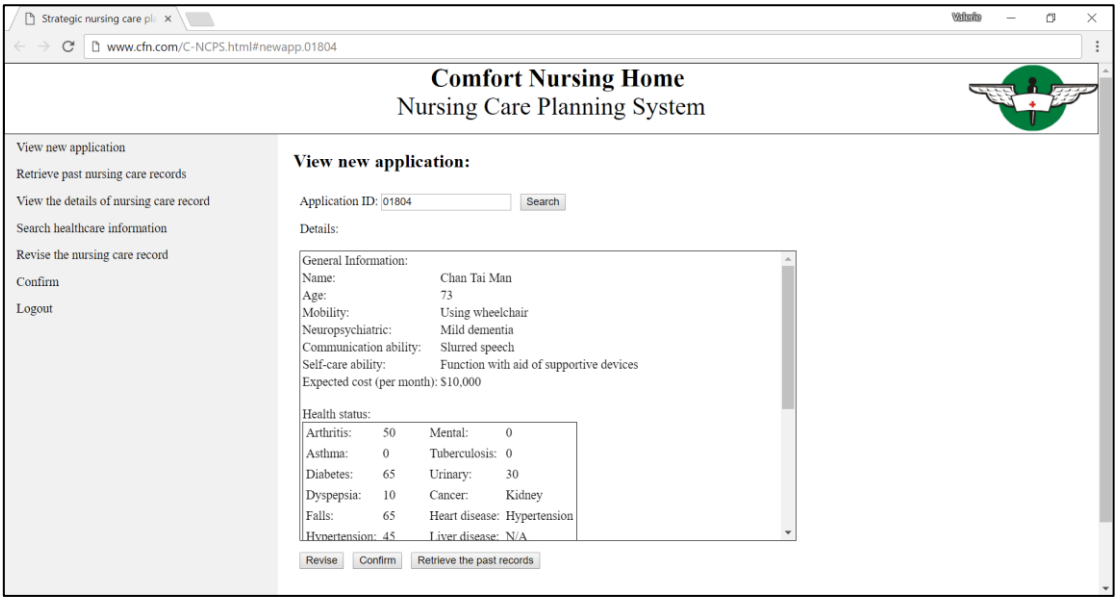

Figure 10. User interface of C-NCPS for displaying the new application

The nearest neighbor method is then used to rank the potential nursing care records according to their similarity value. Before calculating the similarity value of potential nursing care records, it is required to determine the similarity value of individual attributes. In this case, thirteen attributes, as shown in Table 1, are defined as important parameters for calculating the similarity value of potential nursing care records. There are two types of attributes, numeric and textual. The similarity values of the textual attributes are predefined by the admission staff and stored in the case library. In addition, for the numeric attributes, the following formula is adopted to calculate its similarity value.

$$sim(R_{old}, R_{new}) = \frac{(S^o - |T_{new} - T_{old}|)}{S^o} \times 100\%$$

where S^o is the maximum value of an individual attribute, T_{new} is the value the individual attribute inputted by the new applicant and T_{old} is the value of the individual attribute in the potential nursing care records. With the similarity values of individual attributes and their weightings, the similarity values of the potential nursing care records can be calculated. Figure 12 shows the case retrieval process in the C-NCPS. Potential nursing care records with more than 50% similarity to the new application are displayed and ranked in descending order. Based on the results in the retrieving process, admission staff can select the nursing care record with highest similarity value as a reference for formulating the new nursing care plan in the case revision process. Figure 13 shows details of the retrieved nursing care record.

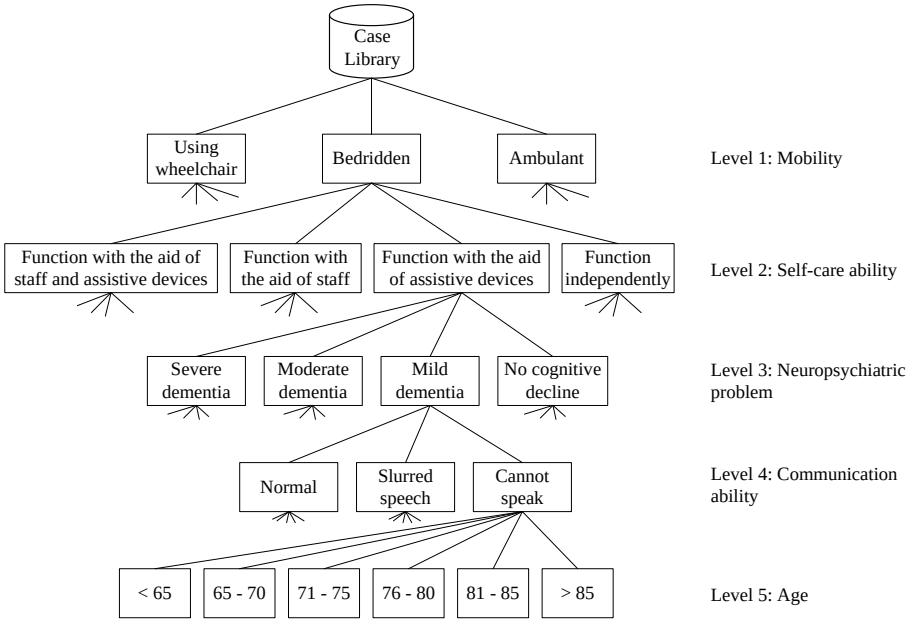

Figure 11. The structure of the decision tree for the inductive indexing method

Table 1. Thirteen attributes for calculating the similarity value of the nursing care records

Attributes	Weighting	Type of attributes	Attributes	Weighting	Type of attributes
Arthritis	0.75	Numeric	Tuberculosis	0.2	Numeric
Asthma	0.35	Numeric	Urinary	0.65	Numeric
Diabetes	0.4	Numeric	Cancer	0.2	Textual
Dysphagia	0.65	Numeric	Heart disease	0.3	Textual
Falls	1	Numeric	Liver disease	0.25	Textual
Hypertension	0.2	Numeric	Expected cost	1	Numeric
Mental	0.7	Numeric			

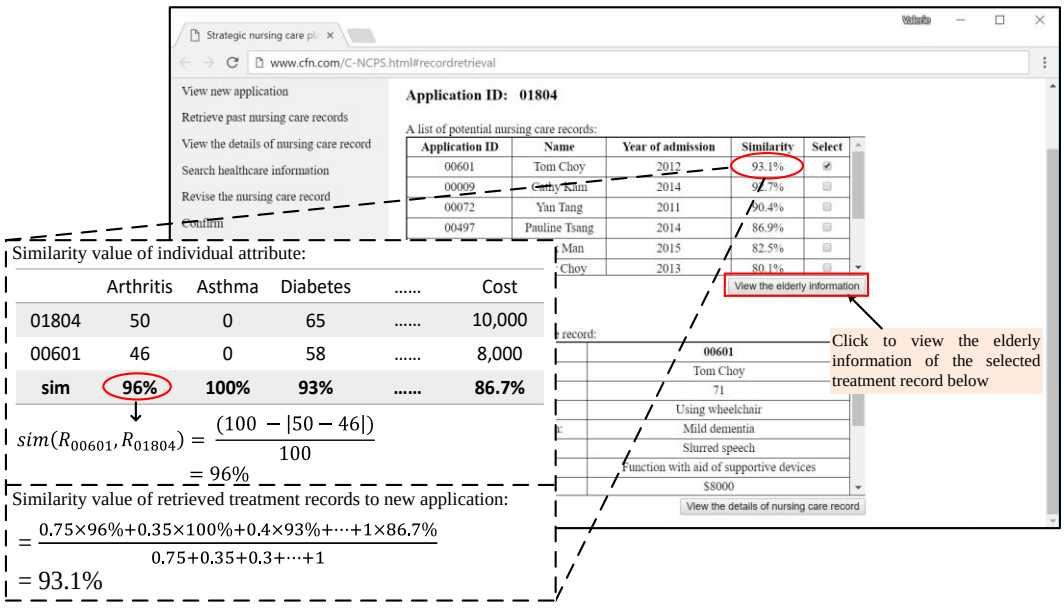

Figure 12. User Interface of the case retrieval process in the C-NCPS

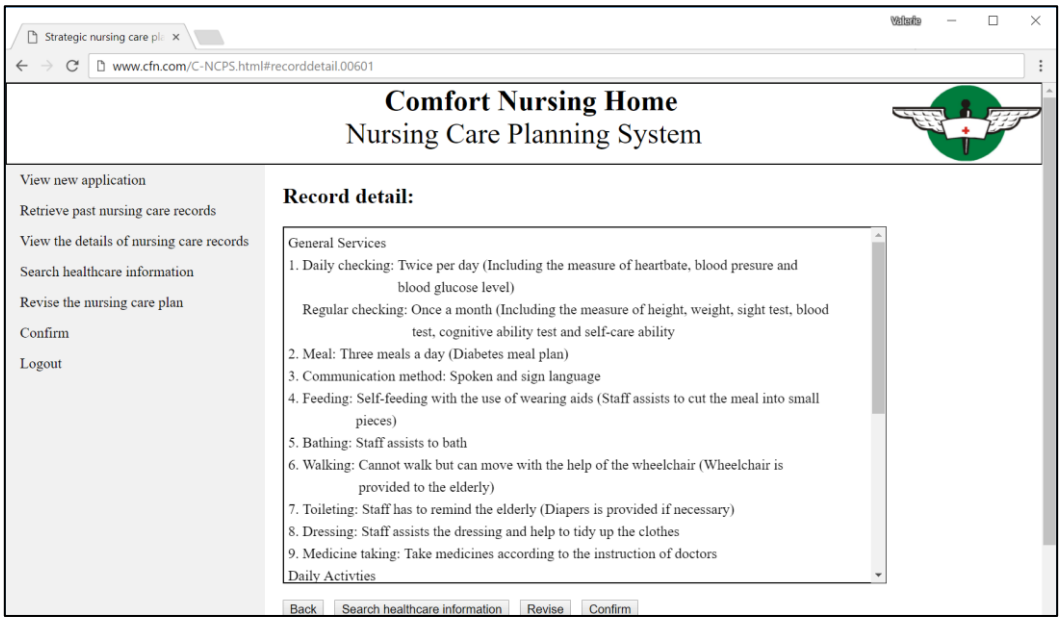

Figure 13. The details of the retrieved nursing care record

4.1.4 Revise the Nursing Care Record by Extracting the Healthcare Information from the Internet

Since the elderly and their families may have specific requirements, the retrieved nursing care record may not fit the new application. Therefore, case revision is adopted to modify the retrieved nursing care record using the text mining technique. In this step, updated healthcare information is extracted from the Internet for revising the nursing care record. In order to reduce the time for searching for healthcare information, it is important to identify the most frequently used websites. Through the consultation with the admission staff, it is found that they are likely to find the healthcare information from online healthcare news and medical databases such as “Modern Healthcare”, “Healthcare Business & Technology”, “PubMed” and “Medical Plus”. Therefore, when a nurse is searching for healthcare information using the C-NCPS, the system will find the articles from these medical websites.

To satisfy different patient and family requirements, nurses try to provide the desirable healthcare services to their customers. Taking a patient with mild dementia and hypertension as an example, since dementia will lead to the memory deterioration of the patient, it may interfere with the daily life of the patient. In addition, patients with hypertension have to have a healthy diet in order to avoid meals with high levels of salt to control blood pressure. Families are, therefore, worried about the safety and health status of the elderly when they are living in a nursing home. They want the nursing home to provide the 24 hours tracking and monitoring so as to prevent accidents occurring. However, from the extracted nursing care records, it is found that the basic daily checking such as blood pressure and heartbeat measures is provided to ensure the health status. On the other hand, cameras are installed in the nursing home to monitor the daily activities of the patient. In this situation, extracted nursing care records cannot satisfy the expectations of the new applicant. Updated healthcare information is needed for revising the nursing care records. With the use of C-NCPS, the admission staff can enter the keywords and then find the related healthcare information to meet the requirements. In this case, “monitoring”, “real time”, “wireless” and “device” can be classified as the

keywords and inputted into the search box. A number of articles and news related to keywords are retrieved and ranked in descending order according to the relevance scores. The admission staff can read the articles and news by category. Figure 14 presents the text mining result using "device" as a keyword.

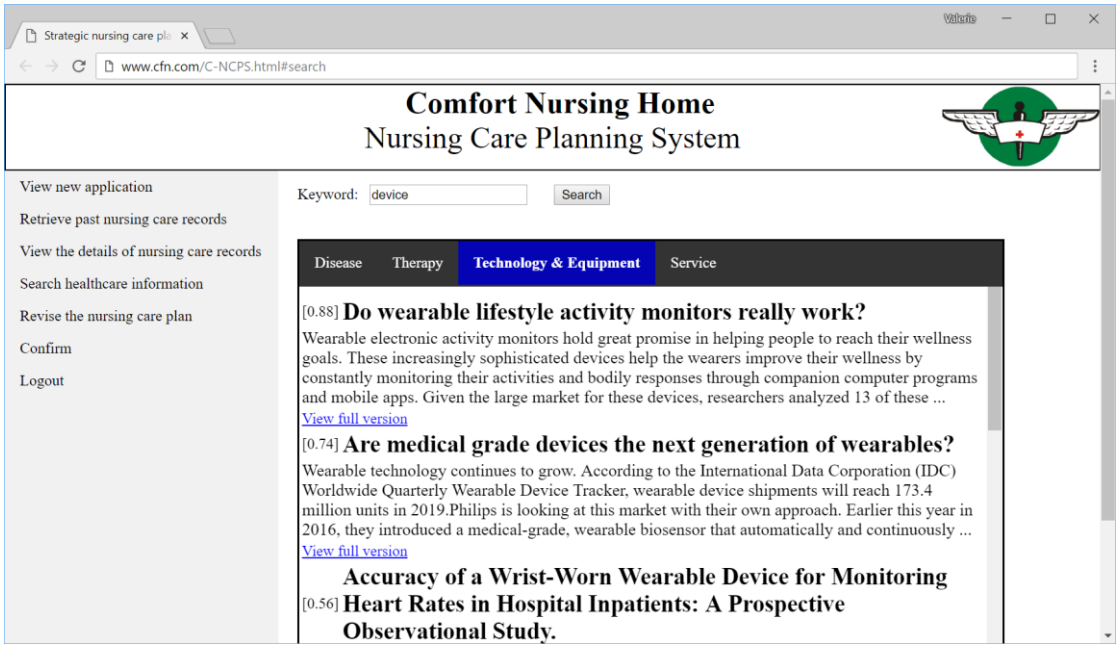

Figure 14. The search result of the C-NCPS

To calculate the relevance scores, first, the TF-IDF weight of keywords has to be measured using Eq. (2). Two parts are involved in the calculation of the TF-IDF weight: the term frequency part and inverse document frequency part. Figure 16 illustrates an example of the retrieval mechanism of articles / news with the top 20% of TF-IDF weight. In the system, there are 500 articles (N = 500) and "device" is inputted as the keyword for searching for the articles and news. It is found that 231 articles and news ($n_j = 231$) contain the keyword "device". Based on the value of N and n_j, the inverse document frequency can be found, which is 0.34. For the term frequency, it is the occurrence frequency of the keyword "device" in the article or news, as the highlighted word in Figure 15. By multiplying the value of the term frequency and inverse document frequency, the TF-IDF weights of articles and news are calculated. The articles and news containing the keyword "device" are then ranked according to the TF-IDF weight in descending order. The top 20% articles and news are extracted and then grouped into the four predefined categories according to their relevance scores using Eq. (4).

Four predefined categories are "Disease", "Therapy", "Technology and Equipment" and "Service". "Disease" refers to the signs, symptoms and causes of diseases. "Therapy" refers to a brief treatment of diseases. It not only involves information on the drugs used, but also includes ways to control and prevent the disease. "Technology and Equipment" refers to the medical technology and equipment that can bring a better life quality to the elderly. Service" refers to the healthcare services that can ensure the health and safety of the elderly and hence improve service satisfaction. Articles

and news that can be classified into more than one category will be classified into the category with highest relevance scores. Figure 16 shows the mechanism for classifying the articles and news into four categories. For example, the relevance scores of the article "Wireless patient monitoring system to transform the Health Care Sector" to "Service" category is higher than that to "Technology and Equipment" category. Therefore, the admission staff only need to read this article in the "Service" category.

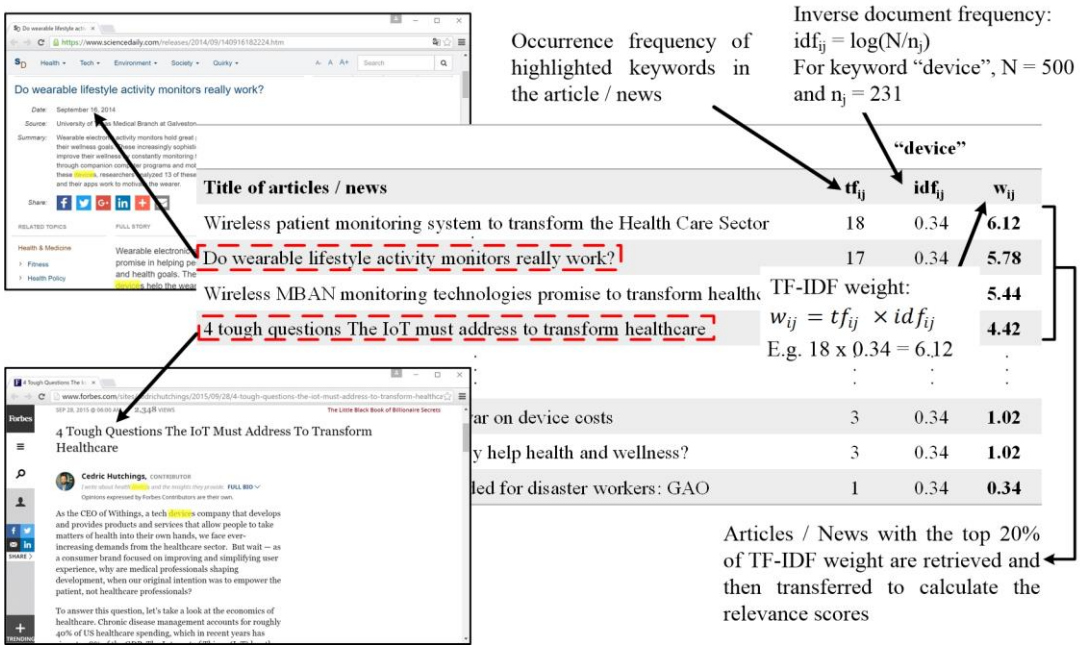

Figure 15. An example of retrieval mechanism of articles / news with the top 20% of TF-IDF weight

An article with a high relevance score is expected to be the most relevant article for providing suggestions for the admission staff in decision making. To further verify the suitability of the article, the admission staff can read a short summary of the article or the full version of the article on its own website. The short summary is generated from the article by the summation of the TF-IDF weight of individual sentences using Eq. (4). After reading the articles and news, it is found that wearable devices can continuous monitor the heartbeat and blood pressure of users. Apart from the biometric measurements that wearable devices can provide, they can also function in location tracking. Based on the healthcare information obtained, the admission staff can revise the nursing care record and decide to adopt wearable devices to track and monitor the health status of the patient. Figure 17 shows the transformation of update healthcare information to the retrieved nursing care plan.

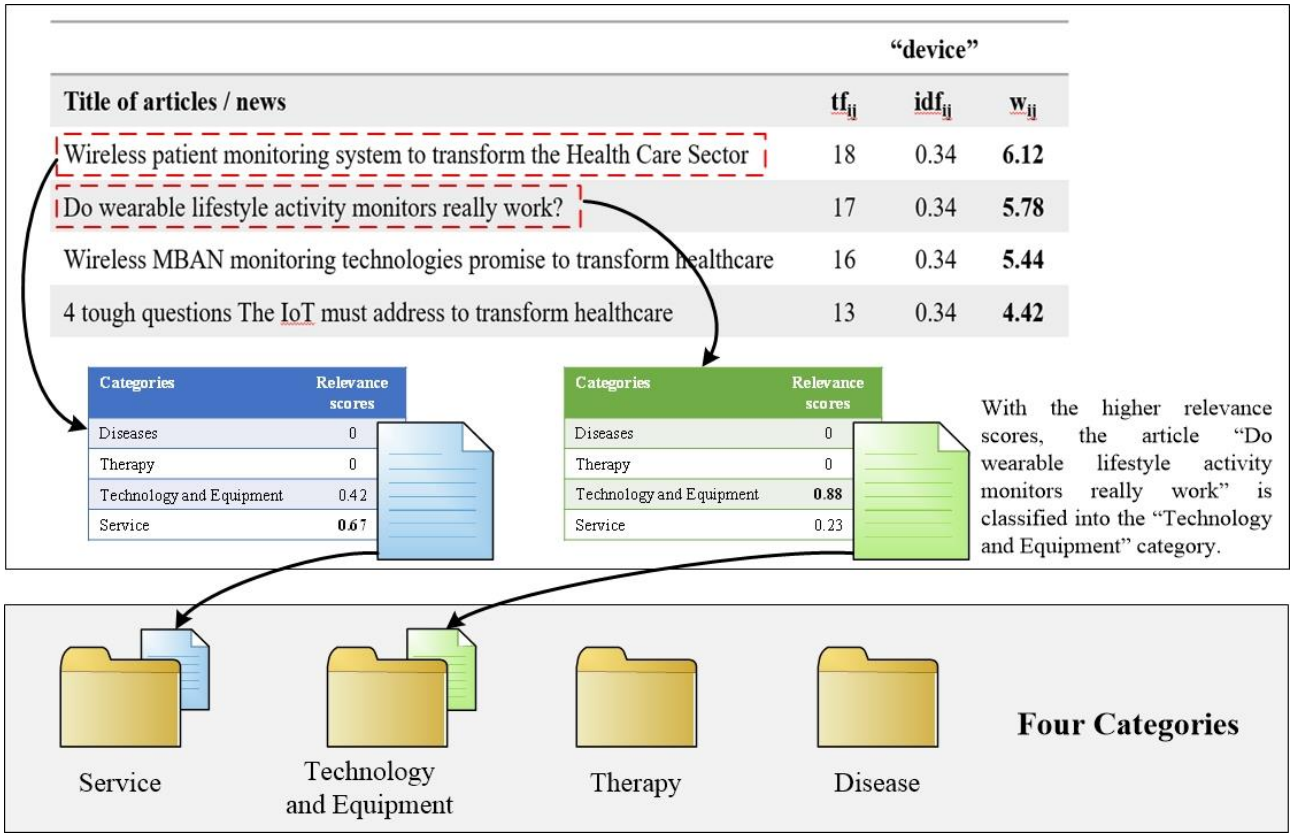

Figure 16. The mechanism for classifying the articles and news into four categories

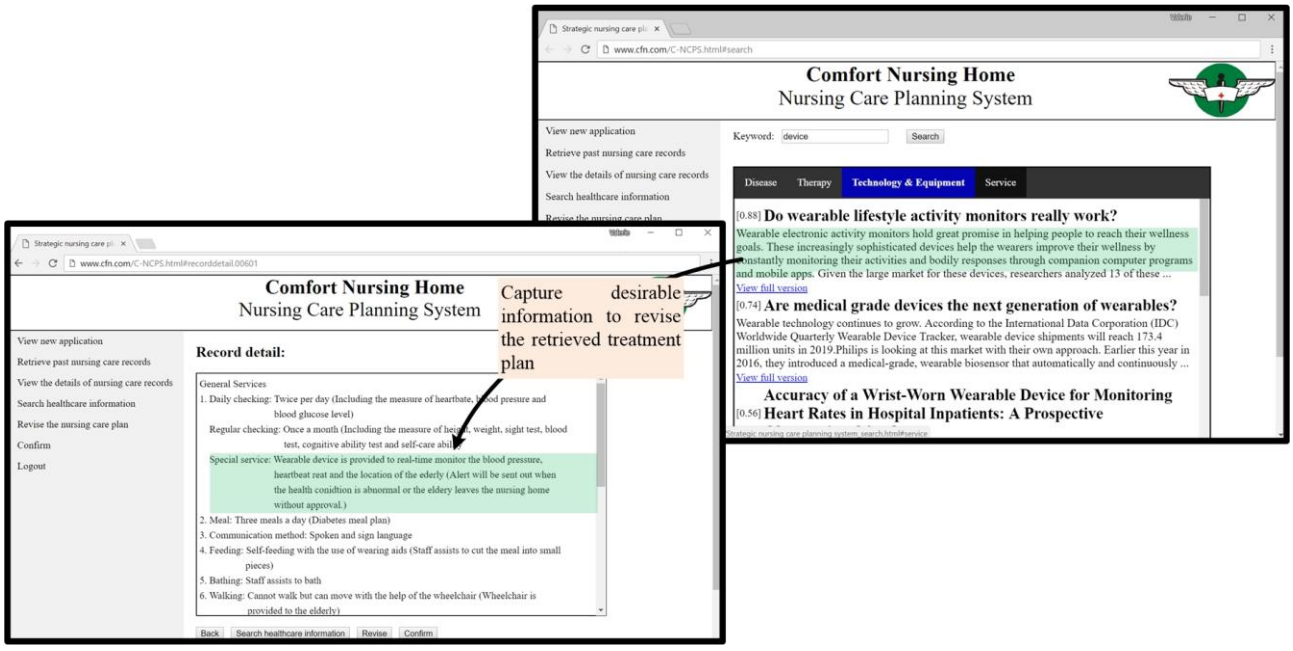

Figure 17. Transformation of update healthcare information to the retrieved nursing care plan

4.1.5 Retain the New Nursing Care Plan in the Case Library

The revised nursing care plan is treated as a new nursing care record and stored in the case library. With the increase of nursing care records in the C-NCPS, the admission staff have a higher chance to

extract the past nursing care records with high similarity values. In addition, the admission staff can obtain the latest healthcare information and hence improve the quality in decision making.

5. Results and discussion

C-NCPS has been developed to assist admission staff in formulating a new nursing care plan with consideration of the expectations of the elderly and their families. By conducting a case study in the Comfort Nursing Home from January 2017 to June 2017, it was found that C-NCPS improves the performance of the admission staff while customer satisfaction is enhanced. In this section, the result of C-NCPS are discussed to validate its significance and contribution. Then, the system performance between the conventional CBR and the proposed C-NCPS is compared.

5.1 Results of C-NCPS in the Comfort Nursing Home

5.1.1 Improvement in the efficiency of nursing care plan formulation

Instead of the traditional nursing care plan formulation based on the personal experience of the admission staff, C-NCPS facilitates the strategic decision making process by adopting the CBR technique for retrieving past similar nursing care records. Table 2 shows the result of the improvement in the efficiency of the nursing care plan formulation. With the use of C-NCPS, the admission staff can take the past nursing care records as a reference and the time in formulating a nursing care plan is greatly reduced from 7 days to 4 days. It implies that there is a 42.8% improvement in terms of time. Moreover, the efficiency of the nursing care plan formulation highly depends on (i) time waiting for essential documents and (ii) time in searching for useful healthcare information. Since verification of the inputted data is the first step in the process of nursing care plan formulation process, missing supporting documents will increase the difficulties for the admission staff in evaluating the accuracy of the information. Within the study period, the admission staff contacted 18 applicants to obtain supplementary documents, and all of applicants were able to upload the related documents within 6 hours. Compared to the traditional approach, the time for waiting for supporting documents is reduced from 24 hours to 6 hours which is a significant decrease of 75%. In addition, the system can assist the admission staff to search effectively for healthcare information among different databases. The admission staff can immediately capture this information for revising the nursing care records. Instead of finding the healthcare information from different databases one by one, the searching time is reduced from 90 minutes to 20 minutes, an improvement of 77.8%.

Table 2. Improvement in the efficiency of nursing care plan formulation

	Without C-NCPS	**With C-NCPS**	**Improvement (%)**
Time in formulating nursing care plan	7 days	4 days	42.8%
Time in waiting for supporting documents	24 hours	6 hours	75%
Time in searching for healthcare information	90 mins	20 mins	77.8%

5.1.2 Improvement in healthcare services satisfaction

In order to measure the performance of C-NCPS in the Comfort Nursing Home, a survey was taken to gather feedback from an elderly group of patients (i.e. 42 respondents), before and after implementing the system. Before implementing the C-NCPS, the satisfaction rate of the Comfort Nursing Home was 49.5% due to (i) slow response in handling new applications, (ii) repeated processing in revision of care plans, (iii) adoption of traditional healthcare services and (iv) high complaint rate. With the use of proposed system, the admission staff can provide an immediate response in handling new applications and hence formulate the nursing care plan. C-NCPS provides suggestions for the admission staff in decision making. This can improve the quality of the preliminary nursing care plan that meets the requirements of the elderly with the adoption of update healthcare information. Without the use of C-NCPS, repeated processing is required to revise the nursing care plan in order to suit the emerging needs. With the use of C-NCPS, the number of revisions in the nursing care plan is significantly reduced from 5 to 1. Due to the improvement in the quality of the nursing care plan formulation, the number of complaints from the elderly and their families is reduced significantly by 60% per month. In addition, the adoption of update healthcare services in the Comfort Nursing Home makes it easier for families to obtain information. Due to the improvement in the above four aspects, the elderly and their family are satisfied with the overall performance of healthcare services provided by the Comfort Nursing Home, and the satisfaction rate increased from 49.5% to 87.2%.

5.2 Discussion on system performance

In the case revising process of the proposed C-NCPS, the past case records with the highest similar values can be modified based on consideration of the needs of the elderly in formulating an appropriate nursing care plan. The text mining technique is adopted to search for update healthcare information for case revision so as to meet expectations. In order to validate the performance of the text mining technique in the case revision process, the effectiveness of the nursing care plan formulation in the conventional case revising approach and the proposed approach are compared. For the conventional case revising process, users modify the retrieved nursing care record based on their personal experience and knowledge. Two indicators, acceptability of the suggested nursing care plan and appropriateness of the healthcare information, are used to measure the performance of the two approaches. Acceptability of the suggested nursing care plan refers to the percentage of the nursing care plan that is accepted by the admission staff and the elderly and their families. Four criteria, (i) cost, (ii) knowledge required for admission staff to apply the new technology in the nursing home, (iii) feasibility of solutions, and, (iv) convenience in use by the elderly, are used to validate the acceptability of the mined text in the nursing care plan (Molony et al., 2018). Apart from the four measurement criteria, a cross validation process was conducted for ensuring the acceptance of nursing care plan. Regular meetings with nursing officers who have had sufficient experience were held for discussing the appropriateness of nursing plan and reviewing the performance of admission staff in implementing such formulation processes. Once nursing care plans of poor quality were rejected, reassessments conducted by nursing officers were needed to re-evaluate the requirements of the elderly based on their health conditions and re-formulate the nursing care plan. The appropriateness

of the healthcare information refers to the accuracy of providing useful healthcare information in the case revising process. Table 3 shows the performance results of the two approaches. Based on the four validating criteria, it was found that 78% of the nursing care plans suggested by the proposed C-NCPS was accepted by the elderly patients and their families, without any modification. On the other hand, the appropriateness of the healthcare information provided by the proposed C-NCPS was 81% which is higher than the information suggested by conventional CBR.

Table 3. The performance results of two approaches

	Conventional CBR	**Proposed C-NCPS**
Acceptability of the suggested nursing care plan	39%	78%
Appropriateness of the healthcare information	56%	81%

In addition, an experiment was carried out to test the consistency of the nursing care plan generated using the conventional CBR and the C-NCPS. Two groups of admission staff (i.e. junior and senior) were randomly selected, with a sample size of each group of 30. They had to use these two approaches to formulate a nursing care plan for 30 new applicants. Group A included junior admission staff with less than three years working experience, while group B included senior admission staff with three years or more working experience. Table 4 shows the results of the experiment.

Table 4. Consistency and variation of nursing care plan with the two approaches

	Conventional CBR	**Proposed C-NCPS**
Consistency of the nursing care plan (Both A and B)	62%	91%
Variation of the nursing care plan		
- Variation of nursing care plan within group A	42%	16%
- Variation of nursing care plan within group B	8%	6%
- Variation of nursing care plan between groups A and B	37%	8%

The following is a summary of the findings:

- Both conventional CBR and C-NCPS approaches can help admission staff to generate consistent nursing care plans.
- With the use of C-NCPS, more than 90% of admission staff can formulate consistent nursing care plans while only 62% of admission staff can formulate consistent nursing care plans using conventional CBR.
- The variation of the nursing care plans within group A for the conventional CBR is significantly higher than that for the C-NCPS.
- The variation of the nursing care plans within group B in both methods is similar.
- The variation of the nursing care plans between groups A and B for the conventional CBR

method is higher than that for the proposed C-NCPS.

The above findings show that since the junior admission staff do not have sufficient working experience, this results in large differences in the nursing care plan formulation. The use of the proposed C-NCPS helps admission staff, especially junior admission staff, to facilitate the decision making in formulating consistent nursing care plans. Thus, the quality of nursing care plan is improved.

6. Conclusions

With increasing considerations of the quality of life, nursing homes are not only required to provide a comfortable and a safe living environment for the elderly, but they also have to offer unique services that can meet the expectations of the elderly and their families. Based on the findings from the literature, it was found that manual nursing care plan formulations are complicated processes due to the large number of evaluations and documents involved. Admission staff currently use their personal experience and judgement to formulate nursing care plans without sharing the knowledge among colleagues. In order to facilitate decision making by the admission staff, in this paper, a cloud-based nursing care planning system(C-NCPS) is proposed with the integration of the cloud computing technology and the novel case based reasoning (CBR) technique. The significance of this study includes the development of a novel decision support system for the formulation of effective nursing care plans through obtaining useful healthcare information from the Internet and past nursing care records, so as to improve the service quality in nursing homes. Through the online application system, the relevant data can be collected in real-time and uploaded to the cloud. With the use of CBR, admission staff can generate an appropriate nursing care plan, based on past nursing care records. This can facilitate decision making and shorten the time in the nursing care plan formulation process. In addition, instead of focusing on the efficiency of the nursing care plan formulation, offering effective healthcare services is essential to improve the service quality and enhance service satisfaction. In C-NCPS, the adoption of text mining techniques in the case revision process allows admission staff to easily identify and obtain updated and accurate healthcare information. This can improve the quality of the nursing care plans generated and service satisfaction can be enhanced.

The proposed C-NCPS has been implemented in the Comfort Nursing Home in Taiwan. It was found that C-NCPS can improve the efficiency and effectiveness of nursing care plan formulation. Especially for admission staff with less working experience, they can make use of these knowledge in C-NCPS to effectively formulate high quality nursing care plans. In addition, by offering high quality healthcare services, the elderly and their families are more satisfied with the performance of the nursing home. However, the proposed system only classifies articles and news into four categories. Further research on the classification categories is required in order to obtain the more accurate results and hence improve the performance of the proposed system. Apart from adopting C-NCPS in nursing homes, it is possible to deploy the C-NCPS in other healthcare areas, such as physical and occupational therapy, for designing the follow-up nursing care plans to patients so as to improve the

service quality. However, data security is one of the concerns when deploying the C-NCPS as patients' information may be disclosed. Hence, healthcare service providers should increase awareness of the security issue so as to protect the personal data of their patients.

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Conflicts of Interest

None

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