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An Intelligent Case-based Knowledge Management System for Quality Improvement in Nursing Homes

Abstract

Purpose – This paper aims at maintaining the high service quality of long term care services providers through an effective knowledge management approach so as to continually enhance the service quality of nursing homes and the performance of its nursing staff continually.

Design/methodology/approach – An intelligent case-based knowledge management system (ICKMS) is developed with the integration of two artificial intelligence techniques, i.e. fuzzy logic and case-based reasoning (CBR). In the system, fuzzy logic is adopted to assess the performance through analysis of the long term care services provided, nurse performance and elderly satisfaction while CBR is used to formulate a customized re-training program for quality improvement. A case study is conducted to validate the feasibility of proposed system.

Findings –The empirical findings indicate that the ICKMS helps in identification of those nursing staff who cannot meet the essential services standard. Through the customized re-training program, the performance of nursing staff can be highly enhanced while the medical errors and complaints can be greatly reduced.

Social implications – The findings and results of the study facilitates the decision making for long term service providers to continuous improve their performance and service quality through providing a customized re-training program to nursing staff.

Originality/value – This study contributes to provide the knowledge management approach for long term service providers to maintain the high service quality in healthcare industry.

Keywords Quality improvement, knowledge management system, long term care services

Introduction

The increasing ageing population is an unavoidable challenge for the healthcare industry all over the world, including Hong Kong (Crimmins & Levine, 2016). According to the Hong Kong Census and Statistics Department, the proportion of elderly persons aged 65 and over is projected to rise markedly, from 15% in 2014 to 36% in 2064. Due to this increasing ageing population in Hong Kong, the needs of public healthcare services are expected to increase continuously (Hui & Yu, 2009). In order to relieve the pressure on the public health services, long term care service providers, such as nursing homes and elderly centers, have been introduced to provide support and reduce the hospitalizations of the elderly (Ouslander & Berenson, 2011; Onder et al., 2012). In nursing homes, nurses and assistants have to perform direct care activities (i.e. feeding, daily health checks, bathing), medication administration (i.e. medicine preparation and documentation), indirect care activities (i.e. cleaning, stock replenishment, equipment setup) and communication activities (Munyisia et al., 2011; Thomoson et al., 2009). Most of these activities have complicated procedures which require professional knowledge and experience to perform so as to provide effective treatment to the elderly (Saxer et al., 2008; Wardh et al., 2012). However, due to the high turnover rate in the healthcare industry, there is a shortage of knowledgeable manpower such that quality services cannot be guaranteed. According to Barry et al. (2012), the knowledge and attitude of nursing assistants are critical factors in managing the quality of life for the elderly. Without appropriate education and training provided to nursing home front-line assistants, the needs of the patients are not recognized or barely detected by nursing assistants, hence no treatment can be provided (Glaister & Blair, 2008; Skar, 2010). Moreover, theoretical studies mainly focused on examining the key indicators for measuring the quality of nursing homes. Research related to the design of systematic approaches and procedures based on relevant knowledge that is applicable for assessing the performance of nursing staff are limited. In order to tackle such

problems, an intelligent case-based knowledge management system is designed to improve the performance and service quality in nursing homes. By integrating fuzzy logic and case-based reasoning techniques, the performance of nursing assistants can be measured systematically while customized re-training programs for quality improvement can be formulated based on previous experience and knowledge. The remainder of this paper is organized as follows. Section 2 reviews the past literature concerning the current situation of the ageing population, quality management in nursing homes, and artificial intelligence techniques for quality improvement. Section 3 presents the design of the intelligent case-based knowledge management system (ICKMS). Section 4 shows a case study to validate the feasibility of the proposed system. Section 5 provides the results and discussion of ICKMS. Section 6 gives the conclusions.

Literature Review

2.1 Nursing industry and knowledge management

Due to the rapid aging population all over the world, the need for nursing homes has significantly increased. An overall healthcare system is usually adopted in nursing homes in order to reduce the operation cost, provide decision support and facilitate the communication between patients, nursing staff and resource providers. A healthcare system is a complex system due to numerous healthcare professionals involved, such as specialists, doctors and nurses (Orr and Sankaran, 2007; Reinhardt, Hussey and Anderson, 2004; Anderson and McDaniel, 2000). The amount of medical knowledge generated by healthcare professionals is enormous and such knowledge is valuable in delivering and maintaining the long-term care quality of nursing home care. According to Spruit et al. (2014), long term care refers to the caring services provided to patients, including the elderly, who have long term or chronic disabling conditions. Currently, the provision for long term healthcare services has been shown to be inadequate due to a shortage of knowledgeable professionals and resources (Yam, Mercer and Wong et al, 2009; Kim, 2001). A shortage of knowledgeable manpower, and a lack of monitoring of medical knowledge and quality indicators are the major problems that hinder government in putting forward an overall healthcare policy to the public. In order to handle such a huge volume of knowledge, knowledge management (KM) is deemed to be a structured approach for managing a process involving various activities under defined knowledge taxonomies (Alavi and Leidner, 2001). With adopting the appropriate KM strategies, organizations perceivably gain the benefits in better operational performance, more business opportunities, and service quality (Evangelista and Durst, 2015).

2.2 Knowledge management in nursing home industry

According to Hauge and Kristin (2008) and Castle and Ferguson (2010), nursing homes should be realized as homes for the elderly to enjoy a good quality of life. Hence, the quality of nursing homes becomes critical in taking care of the elderly in their daily life and fulfill the needs of elderly for achieving elderly satisfaction. To manage the performance of nursing homes, quality assessment is important to identify potential problems and appropriate quality indicators in order to formulate certain improvements, such as training. (Nakrem et al, 2009; Werner and Konetzka, 2010). Castle (2008) examined the relationship between staffing levels and quality in nursing homes and concluded that around 40% of the quality indicators showed a relationship with nursing home staffing levels. Burack et al. (2012) conducted a survey to examine the quality of life of the elderly in nursing homes based on eleven criteria: autonomy, dignity, food enjoyment, functional competence, individuality, meaningful activity, physical comfort, privacy, relationships, security, and spiritual well-being. Based on the above characteristics in nursing homes, KM perspectives can be used to facilitate the enhancement of service delivery and training quality. Bate and Robert (2002) stated that effective KM

localization was important for the improvement of healthcare services, resulting in better collaboration and service quality. Johannessen and Olsen (2003) illustrated that, through the KM, the training can be instrumental and practical in real-life situations so that the sustainable competitive advantages can be developed. Zaim et al. (2013) suggested that the conceptualizing service quality with sufficient knowledge on quality measurement was important in healthcare industry, and the high service quality constituted to strong managerial orientations.

In view of that, most researchers identified the importance of service quality and training in nursing industry. However, the relevant information and knowledge are huge, complex and multidimensional, which is difficult to be managed manually. According to Yousuf Al-Aama (2014), information technology (IT) play an important role to facilitate five KM processes, namely knowledge sharing, generation, transfer, diffusion and codification, in a systematic manner. Therefore, it is essential to establish an appropriate knowledge management system (KMS) so that the performance of long term care services providers, i.e. nursing homes, can be measured and controlled effectively.

2.3. Knowledge management system (KMS)

In general, the applications of KMS provide a user-friendly access to companies' documents, ad-hoc solutions and corresponding information through web-based technologies and computer systems (Rah et al., 2010). It is designed to capture and distribute knowledge so as to obtain border organizational benefits (King and Marks, 2008). In particular, the usefulness and ease of use in KMS are two essential elements for individuals to contribute in the KMS. Due to the complicated and costly implementation of KMS among organizations, seven critical factors, namely benchmark strategy and knowledge structure; organizational structure; information technology; employee involvement and training; leadership and commitment of senior management; learning environment and resource control; evaluation of professional training and teamwork, have explored for successful deployment (Hung et al. 2005). Compared with information and computer systems, the development of KMS is evolutionary and tailored-made by user requirements (Kuo and Lee, 2010). The well-built knowledge pattern should be embedded in the system for facilitating the knowledge acquisition and sharing from knowledge workers. In most organizations, it is inefficient to manage all existing knowledge due to the tremendous volume. The knowledge to be managed should focus on workers' needs and well-defined objectives, resulting in achieving the expected benefits (Kuo et al., 2011).

In the healthcare industry, there are several KMS applications for enhancing the service delivery quality. Hsia et al. (2006) designed a nursing knowledge management system covering assessment, diagnosis, planning, implementation, and evaluation in nursing activities for support nursing processes with professional knowledge. Healthcare organizations have applied strategies in knowledge management for support clinical decision. In addition, the hospital information system (HIS) is necessary to integrate KM so as to improve the competitive edge and quality of healthcare services (Özogul et al., 2009; Yun et al., 2013). Kothari et al. (2011) summarized that the use of KMS is able to prevent knowledge loss/diffusion, achieve continuous learning, improve quality of professional services and meet users' requirements. In order to facilitate the KMS adoption, conducting training can improve the understanding not only the use of KMS, but also the entire service specifications (Yeh et al., 2006; Du Plessis, 2007).

Although the KMS enables the knowledge creation and management to improve the service quality, it is still difficult to solve the complicated real-life decision making problems. Artificial intelligence (AI) is one of the feasible technologies to integrate with KMS for solving well-

defined problem domain and supporting decision-making processes (Nemati et al., 2002). Therefore, the AI-based KMS should be considered in nursing activities, such as nursing home services and nursing service quality maintenance, so that the solutions can be more practical and applicable.

2.4 Artificial intelligence (AI) techniques

Fuzzy logic is one of AI techniques that can convert uncertain information into crisp values and express data in linguistic terms (Nofal and Fouad, 2015). It is able to mimic human thinking and decision-making mechanisms. The rules are presented in an IF-THEN form and stored in a knowledge repository. Instead of a precise cutoff between two categories, fuzzy logic uses the degree of membership between 0 and 1 to represent the true value. Buyukozkan et al. (2011) integrated fuzzy logic and the analytic hierarchy process to evaluate the service quality in the healthcare sector. Lee et al. (2015) adopted fuzzy logic in adjusting service quality towards customer requirements in health services delivery. The above studies show that fuzzy logic is a promising approach in assessing the service quality in the healthcare industry. After assessing the performance using fuzzy logic approach, providing appropriate knowledge and training recommendations to nursing home staffing becomes the next key step for success in improving the quality of the care and life of residents (Mass, 2008). Case-based reasoning (CBR) one of the well-known knowledge repository and learning techniques widely adopted in decision making based on previous experience. It can be used to solve new problems by retrieving similar problems from the past with the expectation that the previous solutions may be useful for solving the new problem (Wang, Chiou, Juan, 2008). CBR has been widely adopted in medical diagnosis (Chattopadhyay et al, 2013; Chung, 2011), treatment planning (Blanco et al, 2013; Petrovic, Mihra and Sundar, 2011) and managing patient records (Miotto and Weng, 2015; Van de Branden et al, 2011, and shows potential in providing knowledge support in the healthcare industry (Begum et al, 2010). However, the use of CBR in retrieving useful knowledge for formulating training recommendations based on the quality assessment result is rare. Hence, there is a need to fill the research gap in providing operation and safety training knowledge in the healthcare industry.

In summary, from the above literature, it is found that there is limited research of AI-based KMS on nursing industry. Integration of the fuzzy logic technique and case-based reasoning to form an intelligent case-based knowledge management system is a feasible solution to measure and improve the service quality of long term care service providers. By formulating a customized training program with relevant knowledge to serving staff based on their performance, previous medical errors and complaints can be greatly reduced while service quality for the elderly can be enhanced.

Design of the Intelligent Case-based Knowledge Management System

In this section, an intelligent case-based knowledge management system (ICKMS) is developed to improve the service quality of nursing homes and the performance of serving staff. The architecture of the ICKMS model is shown in Fig. 1 and consists of three modules: (i) the data collection module, (ii) the service quality assessment module, and, (iii) the knowledge-based continual improvement module.

Module 1 – Data Collection Module (DCM)

In the data collection module, a centralized database is constructed in cloud to store the collected data regarding the information of elderly patients and, nursing home and serving staff. Examples of the three types of collected data are shown in Table 1. In addition, data capturing technology and devices using Bluetooth and radio frequency identification (RFID) are used for

collecting data from the elderly and serving staff. The collected data are then reviewed and stored in the centralized database, using cloud technology, for services quality level assessment in the next module.

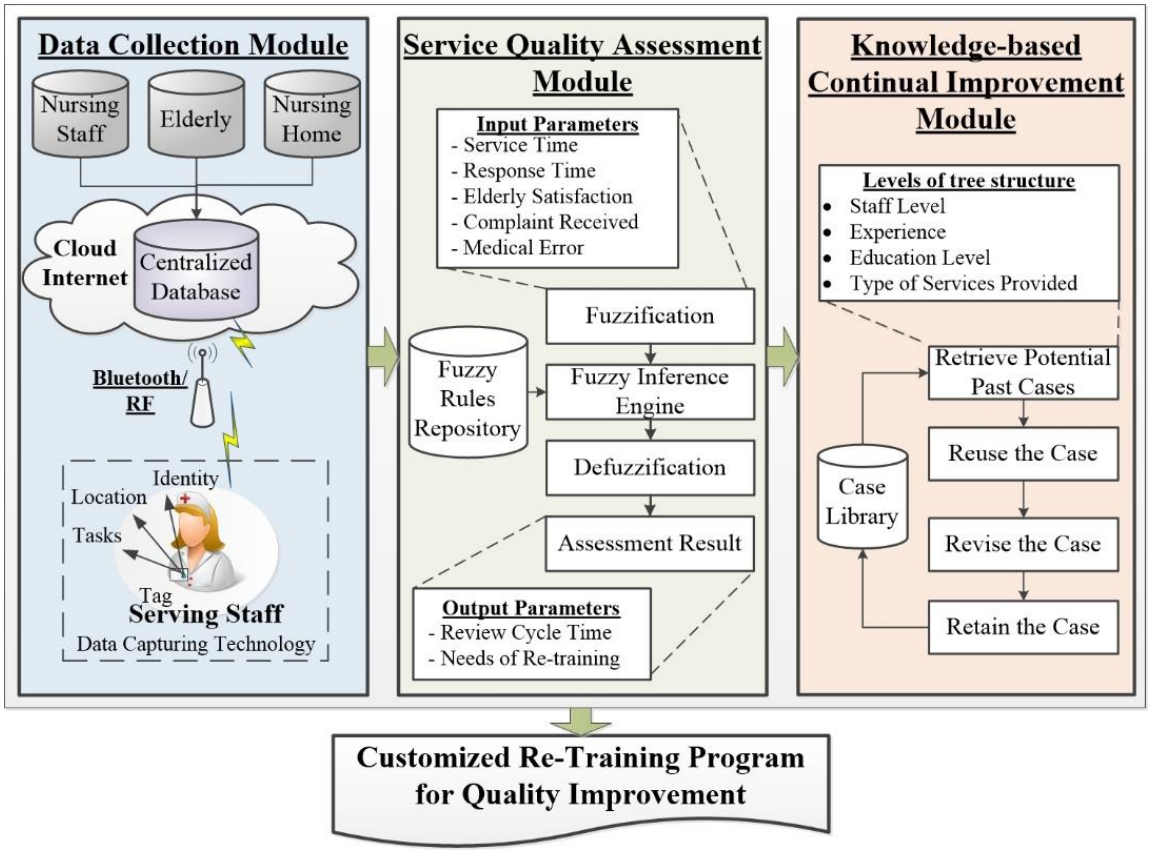

Fig 1. The architecture of the ICKMS model

Table 1. Examples of three types of collected data

Types of data	Examples
Elderly patients	Age, gender, type of illness, feedback,
Nursing home	Services offered, supporting activities, workflow of daily operation
Serving staff	Current staffing level, the type of serving staff,

Module 2 – Service Quality Assessment Model (SQAM)

In order to improve the service quality, it is critical to assess the performance through analysis of the long term care services provided, nurse performance and elderly satisfaction. In this module, fuzzy logic is employed to determine the quality level and the need for improvement. The major processes involve fuzzification, fuzzy inference engine and defuzzification. For fuzzification, the input variables include service time, response time, elderly satisfaction, complaints received and the number of medical errors during the service are retrieved from the centralized database. These inputs are converted into fuzzy sets based on the universe of discourse and the membership function defined. It allows the conversion of numeric values to linguistic terms. The fuzzy sets are then sent to the fuzzy inference engine for converting the input fuzzy sets into an output fuzzy sets through an inference process. It retrieves relative values from the fuzzy rules repository where the knowledge are stored, presented in the form of IF-THEN rules. Finally, output fuzzy sets of service quality assessment are converted into

numeric values in the process of defuzzification. The assessment result, such as adjustment of review cycle time and needs of re-training, are determined in this module.

Module 3 – Knowledge-based Continual Improvement Module (KCIM)

In this module, the customized re-training program for quality improvement is formulated based on the assessment result in SQAM. In order to minimize the medical issues and complaints while maximizing elderly patients satisfaction, a knowledge-based system which can provide possible cause of incidents and preventive action is essential to improve the performance of serving staff. Therefore, case-based reasoning (CBR) is adopted to generate appropriate training solutions with reference to past related records. First, a list of potential past training programs is retrieved and presented in the tree structure, therefore major levels in the tree, such as staff level, experience and education level, are defined for retrieving past similar cases from the case library. Then, the potential past cases are ranked according to the similarity of the past cases and current input. A nearest neighbor approach is employed to calculate the similarity value. After that, the past case with the highest similarity value will usually be reused as the potential solution to the current situation in the case adaptation process. The case and solution is then revised and retained in the case library for future use. Finally, the KCIM will provide a customized re-training program for quality improvement which includes caring services operations guidelines, interpersonal skill training and follow up actions.

Case Study

A case study is conducted in the Comfort Nursing Home, which located in Taiwan, for providing caring and living services for the elderly. The performance review cycle and needs for re-training can be determined to provide the adequate levels of training for the staff.

Company background

The Comfort Nursing Home is one of the largest private elderly caring service providers in Tai Chung, Taiwan, and was founded in the1980s. The company boasts a 7-storey facility with around 800ft^2 on each floor for providing caring and living services, for a maximum of 216 elderly patients. In order to provide the best services to the elderly, this company has six departments to maximize the service quality. They are nursing, caring, public relations, accounting, administration, and, social work departments. New staff members will be given training, and the patient satisfaction is reviewed regularly in regarding to the service performance.

Problems existing in the company

The staff in nursing, caring, and social work departments are the front-liners for taking care of and providing the medical and psychological treatments to the elderly. Their performance directly affects the customer satisfaction and service quality, and therefore they are the critical elements to the business of the nursing home. However, there are two problems that are faced by the company, which include (i) lack of adjustment in the performance review cycle, and (ii) lack of re-training to the current front-line staff.

(i) Lack of adjustment in the performance review cycle

The current performance review cycle is set at regular periods. However, it lacks of flexibility to collect the opinions from the elderly. When receiving numerous complaints and reports of medical errors, the performance review cycle should be shortened, and the provided services should be improved to fit the needs of the elderly.

(ii) Lack of re-training to the current front-line staff

Once the complaints and medical error reports are received, implying low customer satisfaction, the company should provide the re-training for the front-line staff. In addition, the company lacks classifications of the re-training based on the staff level, services provided, work experience, and education level.

Implementation of ICKMS

The application of ICKMS is illustrated by a case scenario to adjust the performance the review cycle, provide the extents of the needs for re-training, and determine the training plans for the staff. In DCM, the data from nursing home, the patients, and serving staff is collected and stored in the cloud database. Table 2 shows seven parameters, from A to G, for the analysis in SQAM regarding the fuzzy logic approach. A to E are classified as the input parameters, whereas F and G are the output parameters. The membership functions of the fuzzy sets are defined by domain experts, as shown in Table 2. The parameters are illustrated by the fuzzy class and the type of membership functions, with the corresponding values. In addition, the fuzzy rules repository, which contains the "IF-THEN" rule, is built in the SQAM to support the fuzzy logic computation.

Table 2 The parameters and membership functions used in fuzzy logic

Input				Output			
Parameters(Unit)[Symbol]	**Fuzzy class**	**Membership function**	**Type**	**Parameters(Unit)[Symbol]**	**Fuzzy class**	**Membership function**	**Type**
Service time (min)[A]	Short	[1, 1, 20, 40]	Trapezoid	Performance review cycle time (%)[F]	Substantially decrease	[-1, -0.75, -0.5]	Triangle
	Normal	[20, 40, 60, 80]	Trapezoid		Significantly decrease	[-0.75, -0.5, -0.25]	Triangle
	Long	[60, 80, 100, 100]	Trapezoid		Slightly decrease	[-0.5, -0.25, 0]	Triangle
Response time (min)[B]	Short	[1, 1, 10, 15]	Trapezoid		No change	[-0.25, 0, 0.25]	Triangle
	Normal	[10, 15, 25, 30]	Trapezoid		Slightly increase	[0, 0.25, 0.5]	Triangle
	Long	[25, 30, 40, 40]	Trapezoid		Significantly increase	[0.25, 0.5, 0.75]	Triangle
Complaint Received (unit)[C] and Medical Error (unit)[D]	No	[0, 0, 1]	Triangle		Substantially increase	[0.5, 0.75, 1]	Triangle
	Rare	[0, 1, 6, 8]	Trapezoid	Needs of re-training (Level 0-10)[G]	Substantial low	[0, 1.25, 2.5]	Triangle
	Usual	[6, 8, 13, 15]	Trapezoid		Significant low	[1.25, 2.5, 3.75]	Triangle
	Frequent	[13, 15, 20, 20]	Trapezoid		Slight low	[2.5, 3.75, 5]	Triangle
Elderly Satisfaction (%)[E]	Poor	[0, 0, 0.25]	Triangle		No change	[3.75, 5, 6.25]	Triangle
	Not good	[0, 0.25, 0.5]	Triangle		Slight high	[5, 6.25, 7.5]	Triangle
	Average	[0.25, 0.5, 0.75]	Triangle		Significant high	[6.25, 7.5, 8.75]	Triangle
	Good	[0.5, 0.75, 1]	Triangle		Substantial high	[7.5, 8.75, 10]	Triangle
	Excellent	[0.75, 1, 1]	Triangle				

To implement the computations of SQAM, the fuzzy logic toolbox in MATLAB is applied to define the input, output membership functions, and fuzzy logic repository. The results of adjustment of the case performance review cycle and the needs for re-training can be generated. For example, there were 30 minutes of service time, 5 minutes of response time, 3 complaints received, 0 medical errors, and 85% customer satisfaction in this period. Through the fuzzy logic toolbox, the results are generated are shown in Fig. 2, where shows the performance review cycle can be increased by 50%, and the needs of re-training for the serving staff is at level 1.25. It implies the elderly are quite satisfied with the current services provided with 30 minutes of service time and 5 minutes of response time. The performance review cycle can be longer to maintain the high customer satisfaction such that less man-hours are used for the performance review. In addition, since the needs of re-training range from level 0 to 10, the 1.25 level of re-training implies the serving staff have provided services in the at an acceptable level, but the provided services still have room to improve further.

The KCIM is used for determining customized re-training programs for the front-line serving staff. There are four criteria to formulate a re-training program, i.e. staff level, type of services provided, work experience, and education levels. With the adoption of CBR, Fig. 3 shows the

tree structure for generating the appropriate training plan. Considering the serving staff in the aforementioned four dimensions, staff in supervisor positions for recording work, have 6-10 years experience and have completed primary school. Therefore, an appropriate past training program can be retrieved from the past similar training programs. Once the most similar training program is selected, it becomes a case in the CBR to be reused in the current training program. Afterwards, the training program and the corresponding current input will be revised and retained in the case library for the next serving staff who needs the re-training.

Fig 2. Results in MATLAB fuzzy logic toolbox

Results and Discussion

This paper proposes the ICKMS to maximize the service quality by the use of DCM, SQAM and KCIM. Through the SQAM, the performance review cycle can be adjusted according to the viewpoints from of elderly patients and serving staff. Through the KCIM, the serving staff, who need to re-train, will be provided with a customized training program. By implementing the ICKMS in the Comfort Nursing Home, it improves (i) the quality of services provided, and becomes (ii) cost-saving in administrative work.

(i) Improvement of the quality of services provided

Through implementing the ICKMS, the serving staff can receive a customized training program according to their personal characteristics. Compared with the uniform training materials in the past, the proposed system can take care of various needs and levels of the staff such that they can fully absorb the knowledge from the training materials. Therefore, the service quality can be significantly enhanced.

(ii) Cost efficiency in administrative work

In traditional administrative work, it involves a component of regular performance review and handling complaints and medical errors. Due to the improvement of service quality, the performance review cycle can become longer, resulting in less administrative work in collecting information from the elderly. In addition, the customized training program does not only improves the services provided, but also reduces the number of complaints and medical errors received. Therefore, the man-hours and costs used in handling the above work can be certainly reduced.

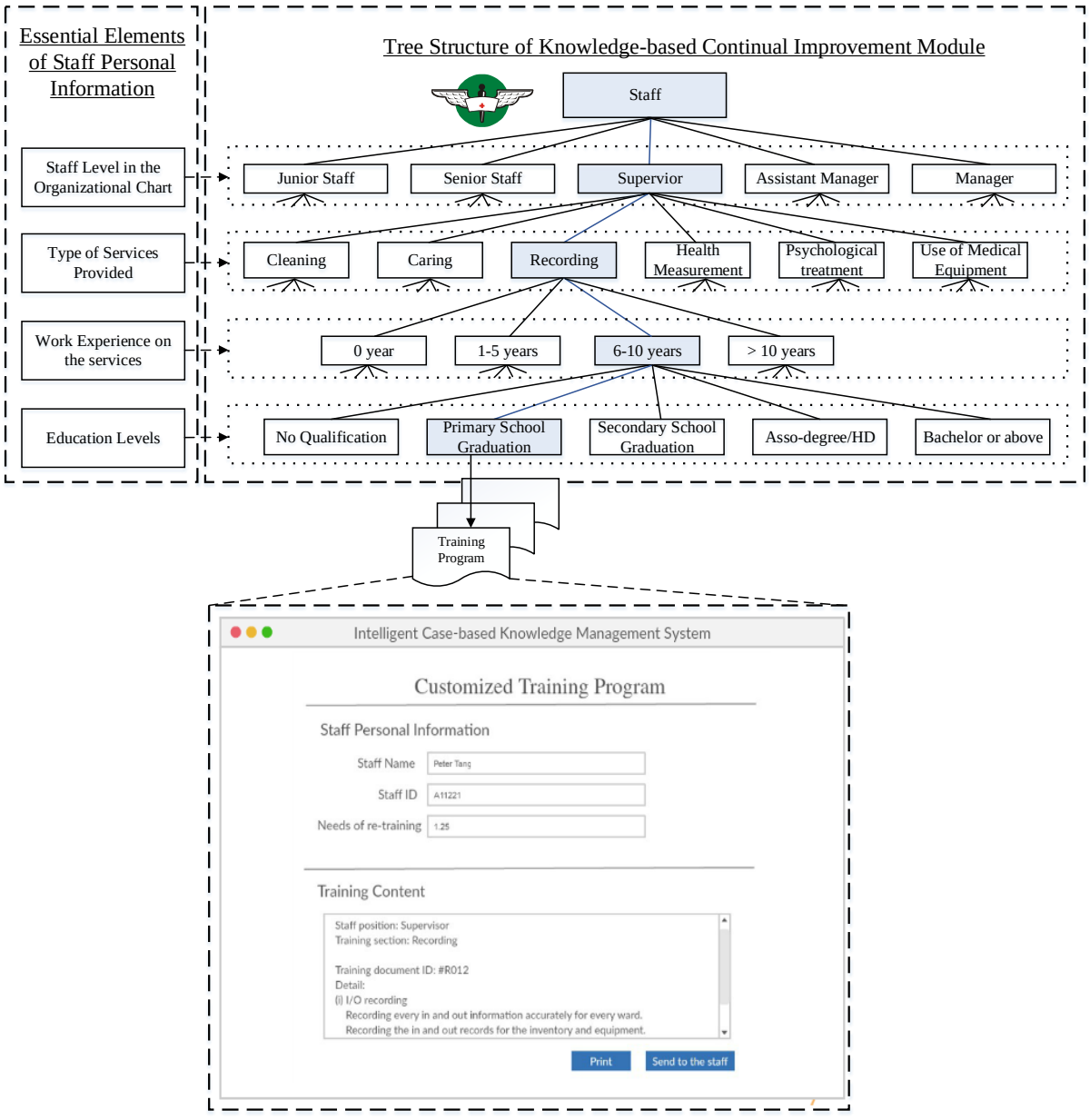

Fig 3. Tree structure and results of KCIM

Conclusions

In order to provide high of quality living to the elderly, well-trained nursing assistants equipped with relevant knowledge are critical to perform various caring activities in nursing homes. This paper aims at designing an intelligent case-based knowledge management system for long term service providers, i.e. nursing homes, so as to continually enhance the service quality of nursing

homes and the performance of its nursing assistants continually. The results will be beneficial to the healthcare industry and the elderly patients who live in nursing homes through the implementation of a comprehensive quality assessment and improvement scheme. This is particularly important as a result of the increasing ageing population in the world. Both the performance of long term care services provided by serving staff, and the service quality of the elderly can be examined holistically by the service quality assessment module. This helps in the identification of those serving staff who cannot meet the essential services standard. As a result, the service quality of the nursing home can be maintained. In addition, through the knowledge-based continual improvement module, a customized re-training program for quality improvement can be formulated based on the assessment result. As correct procedures and knowledge to carry out each operations and steps are very important, the quality improvement plan can provide possible cause of medical error and allow correspondingly preventive action. By so doing, previous medical errors and complaints can be greatly reduced while the service quality of the elderly can be highly enhanced.

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