An intelligent case-based knowledge management system for quality improvement in nursing homes

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Abstract

Purpose – This paper aims to maintain the high service quality of the long-term care service providers by establishing a knowledge-based system so as to 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 the analysis of the long-term care services provided, nurse performance and elderly satisfaction, whereas CBR is used to formulate a customized re-training program for quality improvement. A case study is conducted to validate the feasibility of the proposed system.

Findings – The empirical findings indicate that the ICKMS helps in identification of those nursing staff who cannot meet the essential service standard. Through the customized re-training program, the performance of the nursing staff can be greatly enhanced, whereas the medical errors and complaints can be considerably reduced. Furthermore, the proposed methodology provides a cost-saving approach in the administrative work.

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Practical implications – The findings and results of the study facilitate decision-making using the ICKMS for the long-term service providers to improve their performance and service quality by providing a customized re-training program to the nursing staff.

Originality/value – This study contributes to establishing a knowledge-based system for the long-term service providers for maintaining the high service quality in the health-care industry.

Keywords Quality improvement, Knowledge management system, Long-term care services

Introduction

The increasing ageing population is an unavoidable challenge for the health-care industry all over the world, including Hong Kong (Crimmins and Levine, 2016). According to the Hong Kong Census and Statistics Department, the proportion of the elderly people aged 65 and over is projected to rise markedly, from 15 per cent in 2014 to 36 per cent in 2064. Because of this increasing ageing population in Hong Kong, the need for public health-care services is expected to increase continuously (Hui and Yu, 2009). 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 hospitalization of the elderly (Ouslander and Berenson, 2011; Onder et al., 2012). In nursing homes, nurses and assistants have to perform direct care activities (i.e. feeding, daily health checks and bathing), medication administration (i.e. medicine preparation and documentation), indirect care activities (i.e. cleaning, stock replenishment and equipment setup) and communication activities (Munyisia et al., 2011; Thomson et al., 2009). Most of these activities have complicated procedures which require professional knowledge and experience to undertake so as to provide effective treatment to the elderly (Saxer et al., 2008; Wardh et al., 2012). However, because of the high turnover rate in the health-care 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 and Blair, 2008; Skar, 2010). Moreover, theoretical studies have mainly focused on examining the key indicators for measuring the quality of nursing homes. Research works related to the design of systematic approaches and procedures based on relevant knowledge that is applicable for assessing the performance of the nursing staff are limited. To tackle such problems, an intelligent case-based knowledge management system (ICKMS) is designed to improve the performance and service quality in nursing homes. By integrating the fuzzy logic and the case-based reasoning (CBR) techniques, the performance of nursing assistants can be measured systematically, whereas 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 (AI) techniques for quality improvement. Section 3 presents the design of the ICKMS. Section 4 shows a case study to validate the feasibility of the proposed system. Section 5 provides the results and discussion of the ICKMS. Section 6 gives the conclusions.

Literature review

Current challenges in the nursing industry

Because of the rapidly aging population all over the world, the need for nursing homes has significantly increased. An overall health-care system is usually adopted in nursing homes
to reduce the operation cost, provide decision support and facilitate communication between the patients, nursing staff and resource providers. A health-care system is a complex system because of the numerous health-care 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 health-care 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 the long-term health-care services has been shown to be inadequate because of a shortage of knowledgeable professionals and resources (Yam 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 governments in putting forward an overall health-care policy to the public. To handle such a huge volume of knowledge, knowledge management (KM) is deemed to be an appropriate structured approach for managing a process involving various activities under defined knowledge taxonomies (Alavi and Leidner, 2001). By adopting the appropriate KM strategies, organizations perceive gain the benefits of better operational performance, more business opportunities and better service quality (Evangelista and Durst, 2015).

Maintaining service quality in the nursing industry by the knowledge management approach

According to Hauge and Kristin (2008) and Castle and Ferguson (2010), nursing homes should be realized as homes for the elderly for enjoying a good quality of life. Hence, the quality of nursing homes becomes critical in taking care of the elderly in their daily life and in fulfilling their needs in achieving satisfaction. To manage the performance of nursing homes, quality assessment is important for identifying potential problems and appropriate quality indicators 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 per cent of the quality indicators showed relationships with the 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. On the basis of 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 health-care services, resulting in better collaboration and service quality. Johannessen and Olsen (2003) illustrated, through the KM approach, that training can be instrumental and practical in real-life situations so that sustainable competitive advantages can be developed. Zaim et al. (2010) suggested that the conceptualizing of service quality with sufficient knowledge on quality measurement was important in the health-care industry, and high service quality was associated with strong managerial orientation.

Consequently, most researchers identified the importance of service quality and training in the nursing industry. However, the relevant information and knowledge are huge, complex and multidimensional, and are difficult to be managed manually. According to Yousuf Al-Aama (2014), information technology (IT) plays an important role in facilitating 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 the long-term care services providers, i.e. nursing homes, can be measured and controlled effectively.
Knowledge management system

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). KMS is designed to capture and distribute knowledge so as to obtain broader 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. Because of 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 and evaluation of professional training and teamwork, have been explored for successful deployment (Hung et al. 2005). Compared with the information and computer systems, the development of KMS is evolutionary and tailor-made by user requirements (Kuo and Lee, 2011). A well-built knowledge pattern should be embedded in the system for facilitating knowledge acquisition and sharing from knowledge workers. In most organizations, it is inefficient to manage all existing knowledge because of 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).

Since knowledge has been recognized as an important asset in the nursing industry for enhancing the service delivery quality, the adoption of KMS for sharing and making use of knowledge within the industry has been increasing (Aktharsha et al., 2012; Revere et al., 2007). Health-care organizations have applied strategies that integrate KM for supporting clinical decisions so as to improve the competitive edge and quality of health-care services (Özogul et al., 2009; Yun, 2013). Hsia et al. (2006) designed a nursing KMS covering assessment, diagnosis, planning, implementation and evaluation in nursing activities for the support of nursing processes with professional knowledge. According to Currie et al. (2008), by the adoption of KMS, doctors were able to provide responses to analysis and feedback when incidents occurred. Re-assert control could be established to share learning among them so as to prevent similar incident occurs again. 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. Meanwhile, training sessions and workshops were found to be an effective strategy to share knowledge for enhancing the health-care processes. To facilitate KMS adoption, conducting training can improve understanding, not only on the use of the KMS but also entire service specifications (Yeh et al., 2006; Du Plessis, 2007).

Although the KMS enables knowledge creation and management to improve the service quality, it is still difficult to solve the complicated real-life decision-making problems. AI is one of the feasible technologies for integration with KMS for solving well-defined problem domain and supporting decision-making processes (Nemati et al., 2002). Therefore, an 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.

Artificial intelligence techniques for knowledge management

Fuzzy logic is one of the 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 the 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 service quality in the health-care sector. Lee et al. (2015) adopted fuzzy logic in adjusting service quality toward customer requirements in health services delivery. The above studies show that fuzzy logic is a promising approach in assessing the service quality in the health-care industry. After assessing the performance using the 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 care and the life of residents (Maas et al., 2008). CBR is one of the well-known knowledge repositories and learning techniques that is 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 et al., 2008). CBR has been widely adopted in medical diagnosis (Chattopadhyay et al., 2013; Chung, 2011), treatment planning (Blanco et al., 2013; Petrovic et al., 2011) and managing patient records (Miotto and Weng, 2015; Van de Branden et al., 2011) and shows potential in providing knowledge support in the health-care 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 health-care industry.

In summary, from the above literature, it is found that there is limited research on AI-based KMS in the nursing industry. Integration of the fuzzy logic technique and CBR to form an ICKMS is a feasible solution to make use of the stored knowledge for measuring and improving the service quality of the 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, whereas service quality for the elderly can be enhanced.

**Research methodology**

To maintain the high service quality of the long-term care services providers, a knowledge-based system is designed for enhancing the service quality of nursing homes and the performance of its nursing staff continually. Moreover, the performance of the nursing staff is recognized as one of the important criteria to maintain the service quality of care in the nursing homes (Schnelle et al., 2004). By designing a knowledge-based system, instead of reliance on human knowledge and past experience, the nursing home is capable of creating and adopting the knowledge related to service quality assessment and training program formulation systematically. Because over reliance on human knowledge and past experience in making decisions may bring bias and subjective judgment when making decisions, the research methodology in this study contributes to a systematic approach for improvement. First, standard rules and guidelines in assessing the service quality of the nursing staff are defined. Then, a customized training program based on past similar knowledge is formulated so as to distribute appropriate practices and corrective actions to the staff. Figure 1 shows the research methodology. It consists of four phases which are:

1. problems identification and knowledge goals definition;
2. design of the ICKMS model;
3. case study in a nursing home; and
4. system evaluation.
Phase 1: problems identification and knowledge goals definition

To identify the factors for assessing the working performance of the nursing staff, the relevant KM literature was reviewed, and an in-depth interview was conducted. The representatives of nursing homes, the nursing staff and the elderly were invited to join the interview. Through the interviews with the representatives, the opinions of managers and staff on the difficulty and challenges in providing the health-care service were collected. For example, the nursing staff may express that their workload is too heavy because they have to serve a large number of the elderly and handle various tasks per day. The heavy workload may significantly affect the working performance of the nursing staff. Moreover, the feedback and comments from the elderly were also collected from the interview so as to determine the satisfaction level of nursing home. This information is important for identifying the problems that occur in current operations in the nursing homes. The knowledge goals for improving the service performance were also defined on the basis of the identified problems. Such information was then adopted to design the ICKMS model in Phase 2.

Phase 2: design of the ICKMS model

Two modules are involved in the ICKMS, which are data collection module (DCM) and knowledge generation and acquisition module (KGAM). The architecture of the ICKMS model is shown in Figure 2.

Module 1 – data collection module. Apart from the data collected from reviewing the KM literature and the in-depth interviews, explicit knowledge from written documents, articles, news and video records are required for capturing the knowledge in existing nursing home operations. On the other hand, tacit knowledge is also collected from pictures, images and audio records sources. In addition, data capturing technologies and devices using bluetooth and radio frequency identification (RFID) are used for collecting data from the daily activities of the elderly and serving staff. The collected data are then reviewed and stored in the centralized database, using cloud technology, for generating the knowledge in the next module.
Module 2 – knowledge generation and acquisition module (KGAM). In the KGAM, two aspects are involved:

1. service quality assessment; and
2. knowledge-based continual improvement.

The part of service quality assessment evaluates the current performance of the nursing staff and determines the need for improvement by making use of past experience and knowledge in performance evaluation. First, useful knowledge related to service performance such as service time, response time and service satisfaction, and the corresponding action such as adjustment in performance review cycle time and re-training needs, are created on the basis of the collected data. This knowledge is then stored in the rule-based structure and adopted for assessing the service quality and the need for improvement using the fuzzy logic techniques. The major processes involved in knowledge generation are fuzzification, fuzzy inference engine and defuzzification. For fuzzification, the input variables, including the 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, allowing 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 output fuzzy sets through an inference process. It retrieves relative values from the fuzzy rules repository where the knowledge stored, presented in the form of
IF-THEN rules. The rules stored in the fuzzy rules repository provide a foundation of the past knowledge to be used for determining the service quality in the current situation. Finally, the output fuzzy sets of service quality assessment are converted into numeric values in the process of defuzzification. Through the knowledge conversion process, the assessment results, such as adjustment of review cycle time and re-training needs, are determined in this module.

Subsequently, the knowledge obtained in the part of service quality assessment of KGAM is then transferred and used to formulate the customized re-training program for quality improvement in the knowledge-based continual improvement part. To minimize the medical issues and complaints while maximizing the elderly patients satisfaction, a KMS, which can share and distribute the knowledge to serving staff for providing possible cause of incidents and preventive action, is essential to improve the performance of serving staff. Therefore, CBR, which has the capability in learning and reusing knowledge in problem-solving, is adopted to generate appropriate knowledge for staff training with reference to past related records. These past records contain the knowledge of past service quality evaluation processes and the corresponding training programs to improve the performance. By sharing and applying the knowledge in the KMS, the nursing staff are able to obtain relevant operation procedures and guidelines and hence can provide better performance in the nursing home. To apply CBR in KMS, the past records are first collected for storing in the knowledge database based on the keywords identified. The past records are structured in the form of a tree with different layers, such as staff level, experience and education level, shown from the top level (i.e. general requirement) to the bottom level (i.e. specific requirement). After inputting the criteria to retrieve past related knowledge in formulating training programs, the tree structure of the knowledge database is browsed and searched for potential past records. Then, the potential past cases are ranked according to the similarity of the past knowledge records and current input. A nearest neighbor approach is used to calculate the similarity value. The past knowledge record with the highest similarity value will usually be reused as the potential solution to the current situation in the case adaptation process. The knowledge record and solution are then revised and retained in the case library for future use. The output from KGAM provides a customized re-training program for quality improvement which includes caring services operations guidelines, interpersonal skill training and follow-up actions.

Phase 3 and 4: case study in a nursing home and system evaluation
In Phases 3 and 4, a case study is conducted to demonstrate how the proposed ICKMS model can be applied to maintain the high service quality by making use of the past similar knowledge in performance evaluation. The knowledge stored in the ICKMS model is applied to a Taiwan-based nursing home to validate its model performance. On the basis of the implementation flow of the ICKMS model, the problems in the case nursing home are identified and the knowledge goals are defined. Through the quality assessing processes, useful knowledge in quality assessment and training program formulation can be easily transferred and adopted by the nursing staff for formulating customized training programs so as to achieve the continual quality improvement.

Case study
A case study was conducted in the Comfort Nursing Home, 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 the 1980s. The company boasts a seven-storey facility with around 72 m² on each floor for providing caring and living services, for a maximum of 216 elderly patients. To provide the best services to the elderly, this company has six departments to maximize the service quality. These are nursing, caring, public relations, accounting, administration, and social work departments. New staff members are given training, and patient satisfaction is reviewed regularly, regarding the service performance.

Problems existing in the company
The staff in the nursing, caring, and social work departments are the front-liners for taking care of and providing the medical and psychological treatment 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: lack of adjustment in the performance review cycle and lack of re-training of the current front-line staff.

Lack of adjustment in the performance review cycle. The current performance review cycle is set at regular periods; however, it lacks flexibility in collecting the opinions from the elderly patients. 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.

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 re-training for the front-line staff. In addition, the company lacks classification of the type of re-training based on the staff level, services provided, work experience, and education level.

Implementation of ICKMS
The application of the ICKMS is illustrated by a case scenario for adjusting the performance of the review cycle, providing the extent of the needs for re-training and determining the training plans for the staff. In DCM, the data from the nursing home, patients and serving staff are collected and stored in the cloud database. Table I shows seven parameters, from A to G, for the analysis in the service quality assessment part of KGAM 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 the domain experts, as shown in Table II. 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 service quality assessment part of the KGAM to support the fuzzy logic computation.

To implement the computations of the service quality assessment part of KGAM, the fuzzy logic toolbox in MATLAB is applied to define the input, output membership functions and the 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 min of service time, 5 min of response time, 3 complaints received, 0 medical errors and 85 per cent customer satisfaction in this period. Through the fuzzy logic toolbox, the results generated are shown in Figure 3, where it shows that the performance review cycle can be increased by 50 per cent, and the needs of re-training for the serving staff is at level 1.25. It implies that the elderly are quite satisfied with the current services provided with 30 min of service time and 5 min 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, because the needs for re-training range from level 0 to 10, the 1.25 level of re-training implies that the serving staff have provided services at an acceptable level, but the provided services still have room to improve further.

The knowledge-based continual improvement part of the KGAM is used for determining the customized re-training programs for the front-line serving staff. There are four criteria in formulating a re-training program, namely, staff level, type of services provided, work experience and education levels. With the adoption of CBR, Figure 4 shows the tree structure for generating the appropriate training plan. Considering the serving staff in the aforementioned four dimensions, staff in supervisor positions performing recording duty have six to ten years of 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. Afterward, the training program and the corresponding current input will be revised and retained in the case library for the next serving staff who need such re-training.

<table>
<thead>
<tr>
<th>Parameters (Unit) [Symbol]</th>
<th>Fuzzy class</th>
<th>Membership function</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service time (min) [A]</td>
<td>Short</td>
<td>[1, 1, 20, 40]</td>
<td>Trapezoid</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>[20, 40, 60, 80]</td>
<td>Trapezoid</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>[60, 80, 100, 100]</td>
<td>Trapezoid</td>
</tr>
<tr>
<td>Response time (min) [B]</td>
<td>Short</td>
<td>[1, 1, 10, 15]</td>
<td>Trapezoid</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>[10, 15, 25, 30]</td>
<td>Trapezoid</td>
</tr>
<tr>
<td></td>
<td>Long</td>
<td>[25, 30, 40, 40]</td>
<td>Trapezoid</td>
</tr>
<tr>
<td>Complaint received (unit) [C]</td>
<td>No</td>
<td>[0, 0, 1]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Rare</td>
<td>[0, 1, 6, 8]</td>
<td>Trapezoid</td>
</tr>
<tr>
<td></td>
<td>Usual</td>
<td>[6, 8, 13, 15]</td>
<td>Trapezoid</td>
</tr>
<tr>
<td></td>
<td>Frequent</td>
<td>[13, 15, 20, 20]</td>
<td>Trapezoid</td>
</tr>
<tr>
<td>Elderly satisfaction (%) [E]</td>
<td>Poor</td>
<td>[0, 0, 0.25]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Not good</td>
<td>[0, 0.25, 0.5]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>[0.25, 0.5, 0.75]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>[0.5, 0.75, 1]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Excellent</td>
<td>[0.75, 1, 1]</td>
<td>Triangle</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance review cycle time (%) [F]</td>
<td>Substantially decrease</td>
<td>[-1, -0.75, -0.5]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Significantly decrease</td>
<td>[-0.75, -0.5, -0.25]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Slightly decrease</td>
<td>[-0.5, -0.25, 0]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>No change</td>
<td>[-0.25, 0, 0.25]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Slightly increase</td>
<td>[0, 0.25, 0.5]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Significantly increase</td>
<td>[0.25, 0.5, 0.75]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Substantially increase</td>
<td>[0, 0.25, 1]</td>
<td>Triangle</td>
</tr>
<tr>
<td>Re-training needs (Level 0-10) [G]</td>
<td>Substantial low</td>
<td>[0, 1.25, 2.5]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Significant low</td>
<td>[1.25, 2.5, 3.75]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Slight low</td>
<td>[2.5, 3.75, 5]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>No change</td>
<td>[3.75, 5, 6.25]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Slight high</td>
<td>[5, 6.25, 7.5]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Significant high</td>
<td>[6.25, 7.5, 8.75]</td>
<td>Triangle</td>
</tr>
<tr>
<td></td>
<td>Substantial high</td>
<td>[7.5, 8.75, 10]</td>
<td>Triangle</td>
</tr>
</tbody>
</table>

Table I.
The parameters and membership functions used in fuzzy logic.
Results and discussion
This paper proposes a knowledge-based system, i.e. ICKMS, to maintain the service quality by the use of DCM and KGAM. Through the service quality assessment of KGAM, relevant knowledge can be created and the performance review cycle can be adjusted according to the viewpoints of the elderly patients and serving staff. Through the knowledge-based continual improvement of KGAM, the serving staff, who need to re-train, will be provided with a customized training program based on the knowledge stored in the ICKMS. By implementing the ICKMS in the Comfort Nursing Home, the results show improvement of the quality of services provided, and cost efficiency in administrative work.

Improvement of the quality of services provided
Through implementing the ICKMS, useful knowledge in the form of the IF-THEN rule is created to define the standard rules and guidelines in assessing the service quality of the

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Before implementing ICKMS</th>
<th>After implementing ICKMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of complaints per month</td>
<td>18</td>
<td>7</td>
</tr>
<tr>
<td>Poor attitude of staff</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Poor catering</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Poor living environment</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Number of medical errors occurred</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Mistake in operation procedure</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>Poor recording documentation</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Performance review cycle</td>
<td>Two months</td>
<td>Six months</td>
</tr>
</tbody>
</table>

Table II. Service quality of the nursing home before and after implementing ICKMS

Figure 3. Results in MATLAB fuzzy logic toolbox
nursing staff. Afterward, the result of the service quality assessment is applied to generate customized training programs according to the personal characteristics of the serving staff and the past related experience and records. The proposed ICKMS integrates the state-of-the-art information technology into the KMS so as to improve the adaptability and ease of use. This provides an organized and systematic approach for knowledge creation, sharing, storage and distribution, which can be done in a single tailor-made platform. 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. Table II presents the service quality of the nursing home before and after the ICKMS.

Before the implementation of the ICKMS, customer satisfaction on service quality was evaluated. There are seven areas of service being evaluated, which include attitude of staff, catering, living environment, medical support, activity arrangement, psychological treatment and accident handling. It is found that the elderly patients were generally unsatisfied with the attitude of staff, catering and living environment, whereas complaints...
were also received in these three areas. For the attitude of staff, the elderly patients claimed that staff were sometimes impolite and they did not respond to the request of the elderly patients. For the catering services, complaints were received on poor taste of food and little choice of meal. For the living environment, major complaints were found on the hygiene and cleanliness of bedroom. After implementing the ICKMS, the total number of complaints decreased significantly from 18 to 7 per month. Especially, the number of complaints related to the attitude of staff decreased from 12 to 2, which shows a significant improvement. On the other hand, before the implementation of the ICKMS, medical errors on operation procedure and recording documentation were reported. The mistake in operation procedure was mainly reported during daily health checking process. On the basis of different diseases suffered by the elderly patients, nurses were required to take a blood test or perform insulin injection for the elderly patients who suffer from diabetes. During the blood taking or injection process, nurses did not follow a proper procedure which caused pain or injury to the elderly patients. In addition, nurses are required to record daily health status of the elderly patients as well as the inventory and operations status. However, poor recording documentation would lead to error in managing the daily activities of the nursing home. With the use of the ICKMS, the total number of medical errors decreased from 13 to 5 per month. By providing the training to the staff, the errors because of inadequate operation procedure and poor recording decreased by 50 and 71.4 per cent, respectively.

In addition, the ICKMS enables revision in the training program which increases the flexibility and feasibility of the system deployment. Figure 5 shows the difference of the training program before and after implementing the ICKMS. Before implementing the ICKMS, a standard set of training materials was used to train all nursing staff. The content of training materials include the standard operation procedures on performing daily care and medical treatment, the operating procedures on using medical equipment, recording documentation and emergency treatment. However, staff, who perform different tasks and services with various work experience and education levels, should have a specific set of training materials so as to suit their needs. Besides, according to the complaints and errors received, the training materials should be revised to cover the poor service areas for improvement. Therefore, as shown in Figure 5, the training program is revised to provide corresponding guidelines on improving the document recording process. The corresponding knowledge management processes can be seen as an evolutionary approach such that the quality of the training program and the service delivery quality can be continuously enhanced.

Cost efficiency in administrative work
Traditional administrative work involves a component of regular performance review and handling complaints and medical errors. With the ICKMS, relevant useful knowledge can be gathered, stored and used for improving the service quality in the nursing home. As shown in Table II, it is found that the performance review cycle for assessing the serving staff is increased from two to six months. The longer performance review cycle results in less administrative work in collecting information from the elderly. The customized training program 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.

Conclusions
To provide a high of quality living to the elderly, well-trained nursing assistants equipped with relevant knowledge are critical in performing the various caring activities in nursing
Figure 5.
Difference of training program before and after implementing ICKMS
homes. This paper presents an ICKMS for the long-term service providers so as to enhance the service quality of nursing homes and the performance of its nursing assistants continually. By implementing the ICKMS in the case study of the Comfort Nursing Home, Taiwan, the quality of services in terms of the number of complaints per month and the number of medical errors that occurred each month are improved, whereas the cost in administrative work are reduced with an adjustable performance review cycle. The results will be beneficial to the health-care 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 with the increasing ageing population in the world. Both the performance of the 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 on the basis of the assessment result. As correct procedures and the knowledge to carry out each operation and step are very important, the quality improvement plan based on the past relevant experience and knowledge can identify possible causes of medical errors and allow correspondingly preventive action. By doing so, previous medical errors and complaints can be greatly reduced, whereas the service quality of the elderly can be greatly enhanced. Although the proposed ICKMS provides a systematic approach in service quality assessment and training program formulation, the knowledge created and stored in the form of IF-THEN rules may vary from time to time. When an updated quality assessment criterion and standard are launched, the IF-THEN rules stored in the knowledge database have to be reviewed and refined so as to match the future requirements. To overcome this limitation, further work will focus on designing a mechanism to review and update the knowledge stored in the database periodically so as to ensure the accuracy and adaptability of the knowledge rules.

References


**Further reading**


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