Ontology Based Integration of Residential Care of the Elderly System in Long-Term Care Institutions

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***Abstract*—The problem of global aging of population derived many health care problems. Many countries well aware of the healthcare for elderly population are an extremely important issue. The most important task for long-term care services in the institution are to assess the physical and mental states, and provide the suitable care plans for residents. The application of health information technology can help staffs of long-term care institution to arrange daily care of residents, and provide better personalized care. In this study, we proposed a three-stage ontology development approach that allows members of the interdisciplinary teams to elicit static and dynamic knowledge semantically. So we designed and built a Residential Care of the Elderly System through the concept of different types of care for resident assessment which grades individuals in terms of the severity of five functional status assessment aspects of mental, movement, eating, toilet and medical treatments. We not only can help care staffs understand the needs of residents, but also make personalized care plans and weekly care schedules, in order to achieve the aims of comprehensive assessments and personalized care services. Moreover, resident care quality, care personnel work efficiency, and institution management efficiency can all be improved as a result of the completion of RCES.**

***Index Terms*—ontology, resident assessment, long-term care institution**

I. Introduction

Health Information Technology (HIT) can reduce mistakes in medication/diagnosis, help clinicians obtain patient information in a timely manner, shorten their wait times, and improve care quality and efficiency for patients [1]-[3]. Currently, HIT has been widely applied in health care industries. The common HIT system can help clinicians input medical advices and record prescriptions, medications; electronic medical records (EMR) can catalog and maintain patients' health records, including medical records, images and report inquiries [4], and the standard transmission format has been established to realize the cross-hospital delivery. For patient safety, computer-aided diagnosis and treatment planning have been used to avoid failure to diagnose and improper treatments. The former related literature and care experience have been collected to develop a knowledge base [5].

Care needs assessment is the most important task for long-term care institutions to know care needs before providing required services. Long-term care assessment tools are differing by countries. For example, Japan uses Care Needs Certification Scale [6] to assess body function, living function, actions in daily life, cognitive function, Behavioral and Psychological Symptoms of Dementia (BPSD), social adaptation, medical use situation for the past 14 days and independent degree of daily life, which are classified into 7 levels according to care needs. America takes Minimum Data Set (MDS) as assessment scale [7] which has 18 risk assessment items and assessment criterions. German uses Activity of Daily Living (ADLs) and Instrumental Activity of Daily Living (IADLs) as assessment tools which are classified into 3 levels of care needs in terms of care time needed [8]. Korea employs quantized ADLs to assess care subjects, which is classified into 3 ranks. The major assessment tool used by Holland is International Classification of Function (ICF), Disability and Health was published by the World Health Organization (WHO) to standardize descriptions of health and disabilities, and can be used to assess residents' cognitive functionality using the ICF and its qualifiers. As the classification assessment and assistant degree are based on professional assessment, the assessment criteria are different from each other for different censors. By reviewing former relevant literatures, it can understand that most researchers would refer to the content of MDS when developing comprehensive care need assessment tools. Most software developers also applied MDS as assessment scale for their own assessment systems.

However, the entire assessment process of these systems is complicated and time-consuming, which is not

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suitable for Taiwan's institutions, Taiwan currently has no unified standard for resident care assessment so that the institutions are lack of useful resident needs assessment tool to deliver personalized care and still in the preliminarily stage of employing HIT to help provide proper care services for the residents of LTC institutions. Some commercial MIS systems were designed as general electronic forms systems, so we developed Residential Care of the Elderly System (RCES) to help care staffs to assess residents' overall functional states, care needs, required care time and care methods.

In this study, we cooperated with an 88 beds long-term care institution that belongs to a health service company which provides long-term care services, and has 2 regional hospitals and 5 long-term care institutions. We gathered current care methods of resident, care-related records, assessment scales, and resident assessment procedures. The care staffs also shared their professional knowledge for this project. The RCES was designed by referring Typology of the Aged with Illustrations (TAI) classification, grading concepts and modified part of item contents to satisfy assessment scales in order to be the best applied for Taiwan's residents. RCES includes the basic database, assessment scales, care plan and weekly care schedule. Fig. 1 shows the RCES framework. According to the five aspects of assessment results, RCES can automatically generate personalized resident care plan and weekly care schedule. Therefore, the care staffs can make more flexible care plan for individual residents compared to the traditional care plans. In the institutions, the weekly care schedule of the residents can be implemented in accordance with the estimated resources such as labor power, consumptive materials so as to make effective management mechanism, and operational efficiency.

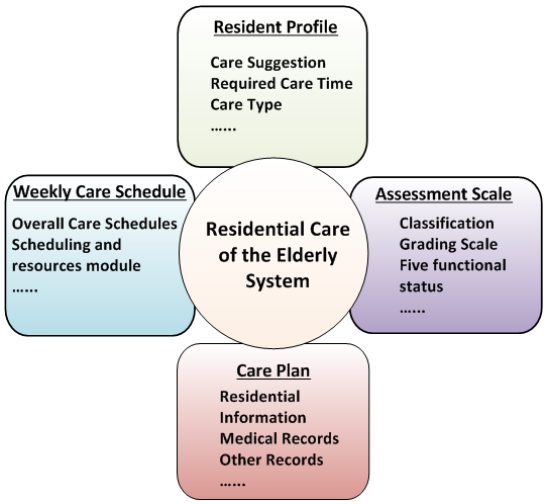

Figure 1. RCES framework.

The objectives of this study are as the following:

- To develop resident assessment tool of long-term care institution with classification and grading concept.
- To build RCES to automatically generate personalized care plan and weekly care schedule for individual residents in the institutions.
- To improve the management efficiency of institutions, the quality of care for residents, and the work efficiency for care staffs.

II. The Conceptual Framework of the RCES

Our methodological approach has three stages: Inception, Object-Oriented Analysis & Design, and Implementation; the approach is illustrated in Table I. Each stage is defined by project content, method, and output. The software development process includes: eliciting information on systems and needs, mapping care processes, and soliciting ideas for the software from institutional care professionals. We developed a prototype software system and incorporated resident assessment processes, assessment questions, care requirements, and required care time. UML methodology was adopted to describe the static and dynamic structure of the RCES to create conceptual models, dynamic models and user interfaces. The proposed RCES is an assistance system for giving institutional residents' assessments, as well as generating personalized care plans and weekly care schedules.

TABLE I. RCES Develop Stages

	Stage 1: Inception	***Stage 2: Object-Oriented Analysis & Design***	***Stage 3: Implementation***
Content	• Data collection: (1) Evaluation scale (2) Record form (3) Resident Evaluation Process (4) Institutions workflow	• Conceptual modeling • Dynamic modeling • User Interface Design	• Database design • Computer Programming
Method	• Literature review • Conducting interview • Requirement analysis	• UML methodology	• Object-oriented programming (1) MS-SQL (2) Visual Studio
Output	• Research scope and design objectives • Requirements	• Conceptual Models • Dynamic Model • User Interface	• Classification and Grading System

World-Wide Web (WWW) is a standardized, cross-platform environment and WWW applications can be effective in creating virtual working platforms, which provide easy ways to collaborate and communicate with co-workers. Therefore, it is appropriate to use the WWW technique to develop an assistive system for managing residents. In this study, we used Microsoft SQL 2008 to build an institutional database which based on the resident assessment scales and added tables per the care professional's requests. We also used the .NET framework and C# programming language was be used for coding the whole system. The system platform is available for the nursing staffs, care personnel and institution managers to get their required residents' information. As shown in Fig. 2, the architecture of RCES we used is described in detail below:

1) Front-end layer: This layer is primarily provided for user interfaces. It contains manipulation of scales, resident assessments, care plan and weekly care schedule generation modules. The resident

assessment module determines the care type and calculates care grade by classification and grading scale. The care plan module provides suggestions for care type and what care aspects should be emphasized. The weekly care schedule module offers overall care schedules to help care staffs deliver better care services for residents. Residents' information includes their personal demographic details, discharged disease abstract, and assessment results, which are all maintained by the interfaces of this layer. Depending on the needs of the care professionals, the interface for the scales is designed to be customizable so that it displays adjustable items and graphically highlights important changes after assessment. It is able to assist care professionals in understanding the changes in complex relationships among the five care aspects.

2) Back-end layer: This layer is used mainly by institution care professionals to set up system permissions, create and modify assessment scales, and estimate overall needed resources. This layer consists of a system control, scale maintenance, care scheduling, and resource allocation modules. The system control module offers the whole system functions for cross-institution management. The scales maintain module is designed to maintain the scale including scale items, weight of items, and estimated care time. Because there are so many uncertainties in Taiwan's policies and factors to assess residents, the use of assessment tools may be changed, so we retained flexibility in this module. The scheduling and resource module can automatically generate weekly care plans for individual residents and calculate the demand of labor powers and resources, which can be the reference for institution managers, in terms of resource consumption.

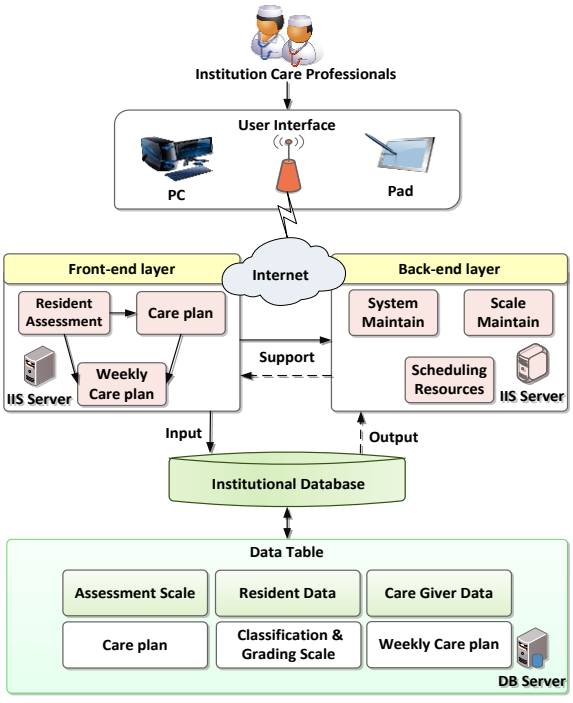

Figure 2. Architecture of RCES.

III. The Conceptual Framework of the RCES

Representation of knowledge becomes an important issue for modern intelligent system. Especially when the question is how it can be effectively used for reasoning as part of the decision making systems. Kuziemsky and Lau [9] pointed out that if the system has been built based on wrong assumptions or poorly articulates user needs then the project will be failed, and they suggested that ontology can assist in health information system design by providing a comprehensive model of the information and process needs for healthcare delivery. Pinto and Martin [10] described an ontological engineering process that includes: specification, conceptualization, formalization, implementation and maintenance. In this study, our methodological approach has three stages: conceptualization, formalization and implementation. Each stage is defined by work content, method and output.

Stage 1: Conceptualization

The first step in conceptualization requires analysis of the research scope and structure. By means of literature review, interview and field investigation, the medical domain knowledge was collected by professionals who are familiar with medical and information technology. There are two tasks done in this stage: data collection and analysis.

1) Data collection: To identify ontology scope and purpose there are three goals the data sources need to accomplish. The first is to be able to validate concepts and processes. The second is to incorporate conceptual models and other relevant research literature as a means of linking research and practice. The third goal involves the use of historical data, such as retrospective cases, to understand current data collection practices and how that data can be formalized into information and knowledge to be returned to end users. We conducted interviews with related system users to understand existing problems and requirements. During the data collection process to determine the scope some specific questions must be posed.
2) Data analysis: The first is ensuring the collected data and workflow must be the same as established models. The second goal is re-viewing literature which is relevant to establish models. The third is how to represent and establish models of the knowledge base, feedback to healthcare providers.

Stage 2: Formalization

The first step in this stage is developing the domain ontology which is a formal model of the concepts and categories. At first stage, we collect the static and dynamic knowledge. After data is collected, we define the lexical and category , identify the semantic relation and data attributes, then illustrate the primary Top-level ontology model and Underlying ontology model.

Stage 3: Implementation

There are two main tasks in the implementation stage. The database development task involves the conversion of domain and ontologies into a physical database model, ensures the appropriateness of the built model. According

to Information categories and processes to contain in two models to build out Sub-Ontology, then established the rules which belongs to inferential knowledge to infer the actual case. The main reason of building the ontology model is to provide the caregivers and institution managers to use in the Long-Term Care Institutions, and ontology model can communicate across different disciplines, it allows caregivers and system developers exchange knowledge on this specialized field, and share this ontology model can reach the value of sharing and using the knowledge of long-term care field.

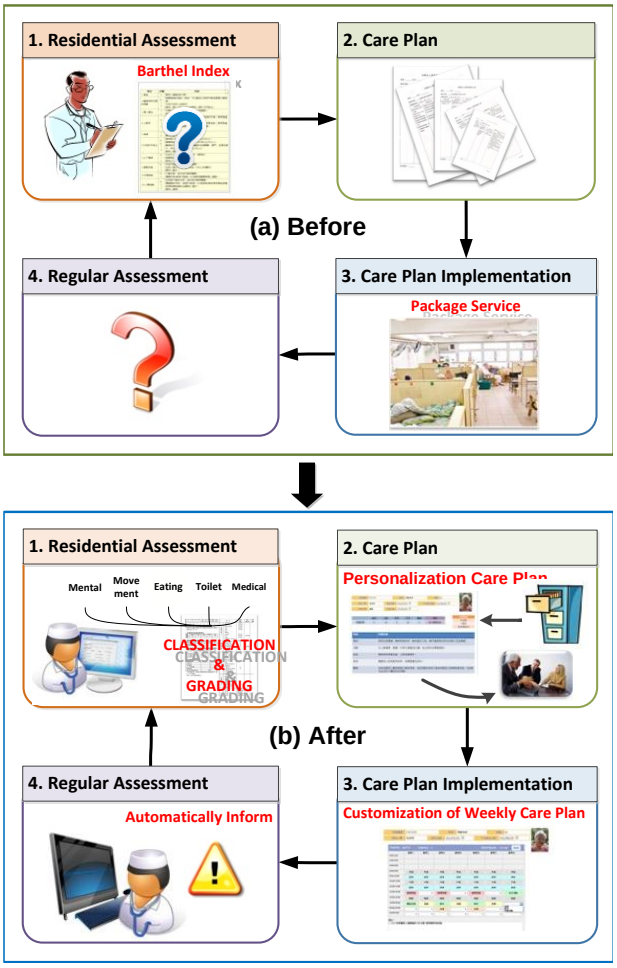

Figure 3. The comparison of resident assessment processes.

Most long-term care institutions in Taiwan only provide "package services" instead of individual services for residents. Fig. 3(a) is the original care flow of residents in the institution. The evaluators manually and subjectively conducted the assessment by various scales as required, such as BI, independent index of ADL, MMSE, SPMSQ and Behavioral Rating Inventory of Executive Function, and then fill in the corresponding care plan according to the situation of residents. For example, if resident encountered the situation of dysphagia, a corresponding care plan of dysphagia should be filled in. If resident encountered multiple care problems, multiple care plans should be filled in. Due to the final care plan for residents are rather complex, the care staffs will care all the residents as the same way. Aside from special medical situation, every resident will use the care plan with same content, including eating, bath, toilet and movement scheduler.

Fig. 3(b) is RCES's innovated classification and grading care process which constructs four stages, namely, assessment of residents, care plan, care plan implementation and regular assessment. The evaluators could make comprehensive assessment to residents by the aid of RCES, including mental, movement, eating, toilet and medical treatment. The RCES will automatically determine the care type and predict required care time after the assessment. It is helpful for staffs in the institution to arrange the floor according to the care type, and arrange suitable labor powers according to the predict care time. Besides care type and time, RCES can automatically generate personalized care plan and weekly care schedule for each resident. Personnel in the institution can explain the current situation and future care methods to residents' families. If there is any amendment needed or care emphasis added, it can be recorded in the weekly care schedule. The whole weekly care schedule is made by different care types by which the nursing personnel can implement the care work. In the future, if there is any change of the residents' situation, the personnel in the institution can rapidly reassess. Moreover, the system will automatically inform to conduct regular assessment every three months so as to make new care plan and weekly care schedules.

The innovation of classification and grading care process assesses by the aid of system instead of the written assessment method in the former procedure. After the completion of assessment, the care plan would be generated automatically which not only improved the situation of filling in many care plan forms, but also increased communication methods with family members of residents. In addition, the care staffs are clear about the care work items, thus they can carry out their care work and have fewer mistakes. The RCES can provide personalized care plan to improve the drawback of package services of the former procedure.

IV. Resident Assessment Tools

The early long-term resident assessment tools mostly focused on the individually assessment of a singular level, and major levels are assessment of cognitive function, assessment of activity function, and assessment of behavioral function [11]. Cognitive function means the mental states including situations of memory, attention, comprehension or language skills, which can tell dementia or learn the declining situation of patient with dementia in terms of cognitive function and the dependence of the cared residents in terms of life [12]. Activity function assessment means the test and quantification of the ability for person to conduct functional movement. It can be used to monitor the whole improvement situation of individual cases, including physical, mental, emotional and social functions.

So it is an important reference to predict the care needs and make care plans. Barthel Index (BI) can be used to check the development situation in rehabilitation field.

Independence in Activities of Daily Living (ADLs) is used to assess the movement independence situation of chronic disease patients and the aged in their daily life. Instrumental Activities of Daily Living (IADLs) is an important index to assess the independence degree of the aged. Functional Independence Measure (FIM) is used to assess the rehabilitation development and result of the multiple disabled patients. Behavioral function assessment is mainly used to assess the behavior problems of the cared persons, especially the patients with brain damage.

Since 1980 WHO proposed the concept of International Classification of Impairment, Disability and Handicap (ICIDH), which influenced the concept of health function assessment and its application, there are many studies indicating the influence of heath function classification on long-term care [13]. Therefore, different health function assessment tools were developed to assess long-term care need. There are two most typical assessment tools listed as follows:

1) Residential Assessment Instrument (RAI) is composed of Minimum Data Set (MDS), Resident Assessment Protocols (RAPs) and Specification. MDS contains all core of items needed to be assessed. RAPs are used to plan nursing care plan, provide diagnosis logic and help evaluators to confirm the care requirements by residents [5].
2) Typology of the Aged with Illustrations (TAI) is composed of classification and grading assessment scale, assessment scale of the needed care scale for the aged, degradation and aging process charts, summary table of each unit, classify the care type and then grade them. The 12 kinds of care types can be specifically divided into 6 scopes and 11 categories. The potential situation of care types, required care contents and notes are provided. Care types, degradation and aging stage of care grades and the care time needed during every stage are demonstrated by diagram [14].

In this study, we employ the concept of classification and grading of disablements to assess the five dimensions of mental, movement, eating, toilet and medical treatments. First, the assessment procedure is evaluated the care grades and then classified care types, residents can be classified to three care types and four care grades after assessment. Each aspect starts with mental which is mainly used to assess cognitive function, including verbal functions and language skills, concept formation and reasoning, perception, orientation and attention. The functional levels are graded in light of cognitive disorder. In terms of movement, it mainly assesses the ability to complete daily activities independently, including personal hygiene, dress and undress, drug usage and shopping. The worst situation is the resident is unable to turn over in bed by himself/herself. In terms of eating, it mainly assesses the ability of swallow and then the situation related to eating, including if one can have dinner by himself/herself, if the fixed dishware is needed and food type. The worst situation is one has to be fed by nasogastric tube or injected nutrition through intravenous. In terms of toilet, it mainly assesses the situation of defecation and micturition, including if one can go to the toilet by himself/herself, if the diaper is needed and the lose control of defecation and micturition. The worst situation is the Foley Catheter is needed. In terms of medical treatment, it mainly assesses the usage of medical treatment, including regular medical examination, emergent medical requirement, medical nutrition management and special medical measures received in two weeks.

Each option has its score. RCES will determine the grade in accordance with the scores to demonstrate the severity of each perspective, the care type is determined according to the grades of each perspective. The care types are "total care", "partial care" and "no care". The total score of all subjects is calculated to judge the required care time. The more scores one gets, the better situation is, and the shorter the care time needs.

V. System Implementation

RCES provides institutional database which stored relevant data, such as the resident's disease history, specific care needs, assessment results, and function of care staff interactions with their caregivers. These data can help care professionals to assess the care needs by their residents' conditions, care plan arrangements, as well as the status of care decisions, care actions undertaken and other relevant information that can aid in providing proper care. RCES provides residents' care types, care methods, estimate care time and customized care plans as well as whole weekly care scheduler for residents. The manager can insert or modify the residents' basic data, hospitalization records and other information. In order to retain flexible extension of the system, RCES followed the modular design principle to make the institution managers modify and maintain assessment scales, in order to increase its usability.

We show some screen layouts, including scales layout, assessment results, customized care plan, whole weekly care scheduler of the RCES. Fig. 4 is the screen that maintains resident's basic information including families' information and admission note. Fig. 5 is the screen that sets scale's subjects and options, institution super manager can modify scale contents. RCES provides function to set the classification and grade of various residents. Fig. 6 is the assessment results determined by RCES for resident, which shows the recommended care type, care grade and required care time as graphic integration table. Institution managers and nursing staffs can learn the overall situation and care needs of the residents by the information shown in Fig. 6. Fig. 7 proposes the customized care plan suggestion which put emphasize on each aspects of assessment results. Care staffs can follow the contents of care plan to implement their care works. Fig. 8 is a weekly care scheduler which shows the care methods and care notes of the residents in different stages by timetable. During the communication with families of the residents, residential care staffs should record the additional requirements by in the sheet.

Figure 4. Basic information of resident.

Figure 5. Scale contents maintenance.

Figure 6. Assessment results of resident.

Figure 7. Customization care plan.

Figure 8. Customization weekly care plan.

VI. Results and Discussions

This study develops residential care of the elderly system of long-term care institution with classification and grading concept on ontology-based model. It conducts assessment based on five perspectives, classifies residents into different categories, and carefully grades care needs in terms of severity. RCES system offers personalized care plans and weekly care schedulers which make the residents' care methods more flexible than that of the former "package services". The major purpose of this study is to offer residents personalized care and better service quality by improving the care process of residents on the basis of RCES. During the research, we found that residents' weekly care schedulers can be employed to estimate the required resources of institution, including care labor power and consumptive materials. Currently, RCES is under testing with our cooperative institutions. We sincerely hope to offer an assessment framework sample of long-term institution in Taiwan, which can be widely used in the future and plan to cooperate with hospitals, making the system serve beyond institutions and realize seamless integration in hospitals.

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