Knowledge Management System in Falling Risk for Physiotherapy Care of Elderly

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Abstract— **This paper describes the elderly healthcare research project affected by a fall. The decision support system is proposed as knowledge management method, including knowledge engineering to acquiring the expert's heuristically diagnostic knowledge and sharing this knowledge to the physiotherapist in the form of tool and application at the right time. This paper outlines a Knowledge Management System (KMS) to diagnose falling patterns in elderly people using Motion Capture Technology. The idea is to integrate an appropriate procedure including case based reasoning and motion capture to provide a decision support system. The diagnosis information derived from the process of KMS helps support the physiotherapist to determine serious falling risks in the elderly and recommend guidelines for medical treatment. The evaluation result shows an efficient performance with 80.95% of precision when using the Assumption Attribute category criteria with K_{NNR}=3. Furthermore, the result of KMS-EUCS shows a high satisfaction from the users with 97.50% of satisfaction in a community of practice scenario. This can confirm the successful of KMS approach within the falling risk screening procedure.**

I. INTRODUCTION

Many surveys have reported that during everyone's life time; a person will have at least two bad falls. This possibly cause severe problems later on in life with 72.4% affecting the Musculo Skeletal System and 90% of these relate to three issues: gait, balance and mobility. Consequently, physiotherapists have to diagnose elderly patients as currently 11% of Thailand population is aged over 59 years and the percentage will be increasing up to 22% by 2045.

Unfortunately, the number of medical experts is not enough for the increasing numbers of elderly population and this could have serious consequences in the near future. Adequate care of the elderly is essential and challenging for planning health and social policy; this forces health providers to look for innovative approaches given the insufficient and limited human power and financial resources. It is also important to train professional staffs and carers, and physiotherapists in particular, to manage the care for the elderly and provide relevant treatment and physiotherapy to improve the quality of life of the elderly population.

The governmental agencies try to solve the urgent problem by reducing the demand of the medical expert with the trained physiotherapist. Their experience through training and mentoring influences the physiotherapist's knowledge sharing behaviour. In order to transfer the knowledge among healthcare practitioners, the communities of practice (CoP) is emphasised [1]. Therefore, it is essential to build knowledge sharing system by letting the medical expert shares their specific medical expert knowledge associated with the care of elderly injuries and disseminates it to the physiotherapists for knowledge reusing. The process shows the mechanism of Knowledge Management (KM).

In this paper, the proposed framework of decision support system (DSS) applies knowledge management, including knowledge engineering e.g. acquiring the expert's diagnostic knowledge and knowledge sharing to the physiotherapist. The research outlines a Knowledge Management System (KMS) to diagnose falling patterns in elderly people using Motion Capture Technology. The idea is to integrate an appropriate procedure including case based reasoning and motion capture to provide a decision support system. The diagnosis information derived from the process of KMS helps support the physiotherapist to determine serious falling risks in the elderly and recommend guidelines for medical treatment.

II. THEORATICAL BACKGROUND

A. Knowledge Acquisition in Healthcare

Chakpitak [2] has described the processes of KM into six major activities; 1) Knowledge Audit, 2) Create Business Framework, 3) Knowledge Analysis and Structuring, 4) IT-Based Knowledge Management Systems, 5) Foster Application, and 6) Performance Measurement. Based on KM aspect, Case Based Reasoning (CBR) is the core application to capture, distribute and reuse the knowledge as a knowledge cycle of typical KM solution (Fig. 1).

Practically, the medical experts diagnose their patients by their own heuristic reasoning. As in the emergency department, the physicians choose the treatment plan for their patients with the decision taken in very short period of time from their experience [1]. In addition, the medical experts always distribute their opinion or knowledge regarding with

the theory rather than their heuristic knowledge and they often leave and take the knowledge and skills with them. This heuristic knowledge is often classified as tacit knowledge which is the knowledge and skill that is hard to describe e.g. experience and native talent [4]. Therefore, it is difficult to elicit the knowledge and disseminate to the physiotherapist. To avoid this issue, the knowledge acquisition is focused. Knowledge acquisition process is the important step in Knowledge Management System (KMS) development [5]. It transforms the experts' tacit knowledge to be the explicit knowledge by using manual methods such as interviewing, tracking the reasoning process, and observing documented and undocumented knowledge [4]. In other words, it is the process to find 'what' and 'how' the knowledge is used. The explicit knowledge is written down and stored into the KMS, then is applied to teach to others. Hence this paper aims to assist physiotherapist in monitoring the elderly and providing a rehabilitation programme relevant to their injuries trough the KMS.

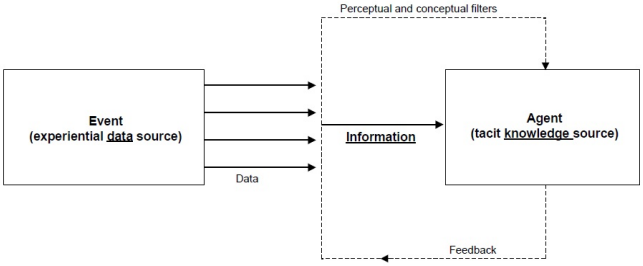

Fig. 1 KM cycle [3]

B. *Knowledge Management System through Case-Based Reasoning*

In order to use the acquired knowledge stored in the KMS, there is a need of intelligence tools to retrieve the right knowledge for supporting the physiotherapist. This tool must be included in the KMS for representing the expert's explicit knowledge to the physiotherapist. This signifies the concept of knowledge representation with the need of retrieval function through the existing system. In this study, the advantage of similarity relation in CBR is used to represent the knowledge from the system in order to disseminate a useful practice to the physiotherapist.

Many researchers have claimed that CBR is the best KMS mechanism which develops more easily than rule-based or model-based approaches where theory is the primary guide to problem solving and their solutions are not easily reusable [6]. The cycle of CBR, including retrieve process, reuse process, revise process and retain process, is obviously correlated with the knowledge cycle. Therefore, the strong association of these two cycles can describe an approach of CBR for developing of a knowledge management system [7]. There are a number of research activities that illustrated a relationship of CBR and KM. In 1999, the Association for the Advancement of Artificial Intelligence (AAAI), formerly the American Association for Artificial Intelligence, started establishing the CBR and KM-related event that was focusing on the requirement of CBR to make an effective contribution for KM. After that, the AAAI continued to annually organize the event. In Germany, the committee of German Workshop on CBR had named their CBR workshop as "German Workshop on Experience Management" since 2001.

Furthermore, the relationship between CBR and KM is also evidenced in a plenty of publications and books. In an earlier decade, Gronau and Laskowski [8] tried to integrate the CBR component into the KM systems. At that time the KM system worked as knowledge discovery services, an Information Retrieval (IR) approach. Therefore, the CBR could extended the performance of the KMS by taking a user's search query as a case for CBR process. Another research that stated the relation of KM and CBR was trying to view the KM as a CBR application [9]. In this research, they described the same principal goals of KM and CBR which are capturing and reusing of the experience or knowledge and also described the less emphasis of CBR in KM about knowledge creation and sharing. Then, they synchronized these KM and CBR frameworks within the DSS approach by proposing a Case-based KM process. This process promoted the KM as a solution for DSS and CBR as the best DSS framework for KM. Similarly, Watson [3] demonstrated that CBR was a suited methodology for KM system by matching CBR process with the KM cycle indicated by Boisot [10], see Fig. 2.

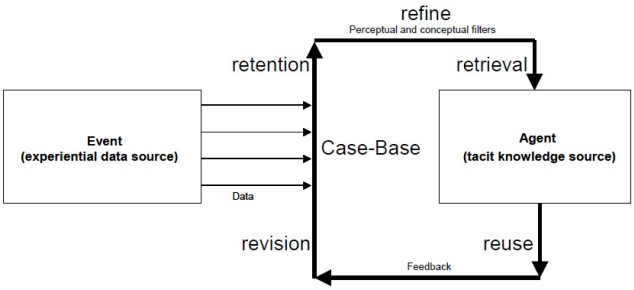

Fig. 2 The CBR cycle supporting Knowledge Management [3]

In this diagram, CBR is matched KM's requirement for; acquisition (revision and retention), analysis (refinement), preservation (retention) and use of knowledge (retrieval, reuse and revision). In recent years, the domain of KM/CBR relationship has been expanding to a multidiscipline research. Mansar, Marir and Reijers [6] used CBR as a KM technique for supporting knowledge transfer strategies in business process reengineering consultancy. They designed a KMS framework and demonstrated through knowledge acquisition and knowledge representation. This system will be used to provide tool that supports knowledge creation, sharing and transfer mechanisms for the consultancy firms or any organization. Bergmann and Schaaf [11] addressed the relations between ontology-based knowledge management (OBKM) and Structural Cased-based Reasoning (SCBR) by showing a strong relationship of both approaches which respect to technological and methodological issues. Their strong relationship introduce similarity model to become part of the future extension to knowledge representation standards.

CBRKM system structure was proposed to support KM activity in industry, by Wang and Hsu [12]. They used this Web-based CBR model to implement a PC troubleshooting KMS for sharing troubleshooting experience of the engineers. Althoff and Weber [7] developed two core KM approach to manage an experience by applying the CBR framework as a foundation of an organizational systems.

Watson [13, 14] described relation of KM and CBR within the books by presenting a corporate memory from CBR perspective and its application. In Bergmann's book, "Experience Management: Foundations, Development Methodology, and Internet-Based Applications", all aspects of CBR application were shown as an example of experience management [15].

Building KMS for sharing the tacit knowledge of the medical experts facilitates the clinical communities of practice (CoP) and avoid disruption in knowledge sharing among the formalization networks. However, healthcare organizations have begun to lose this valuable knowledge as the experts are often retired. This affects the loss of valuable knowledge and personal skills. Besides that, the medical experts are the academicians who always distribute their opinions or knowledge regarding with the theory rather than their heuristic knowledge. As a result, it is difficult to elicit the knowledge and disseminate to the physiotherapist as their culture wherein senior practitioners take an active role in guiding less experienced practitioners [1].

To solve this problem, the development of KMS including DSS approach is required. Generally, KMS involve the procedure of create, capture, refine, store, manage and disseminate knowledge. As mentioned above, the main problem of medical experts in healthcare organization is the knowledge acquisition phase; knowledge creation and caption which are the procedure in KMS development.

III. Delivering of Physiotherapy Care for Elderly using Knowledge Management System

There are increasing research activities and governmental strategies addressing the challenging health care issues associated with the aging population. The demands associated with their health care impose a substantial financial and social burden on economies as a whole, because the elderly require more medical care than younger people. This paper focuses on the health care issues of the elderly in Thailand.

Given the change in population profile a greater demand in the number of physiotherapists is needed to support the health care needs of this expanding sector of the population. Whilst various governmental agencies are addressing this problem through training and curriculum reform the current demand for physiotherapists outstrips current supply. Consequently there is a need to develop innovative approaches to train as well as to support the physiotherapist community in providing the relevant health care for the elderly.

Physiotherapists are often required to help patients who are recovering from orthopaedic surgery. Nowadays, visual analysis of human motion is one of the most active research topics in computer vision. The detection, tracking and recognition of the movements are involved in a number of researches toward the development of visual analysis systems in order to help the clinicians and their patients. In this paper, DSS and CBR have been included in order to support physiotherapists by understanding of human behaviours from image sequences, since AI techniques are necessary in this domain.

By using the Motion Analysis System, physiotherapist could monitor and analyse the movement of the elderly, where all the motion data were collected. These participants were asked to walk along naturally to capture different values from the motion capture system. This system generated a positional data of each elderly person, which was then imported into the KMS in order to calculate the biomechanical parameter regarding the explicit knowledge by the medical experts. In the meantime, the participants were also asked to fill-in the questionnaire. The idea was to gather the participants' daily living activities (behavioural data). The data collected from returned questionnaires were analysed, summarized and stored in the KMS in order to acquire the behavioural parameters of the elderly.

In practice, the doctors, who were the medical experts, diagnose their patients by their own heuristic reasoning. In terms of computing, each medical reasoning procedure was regarded as an independent knowledge problem solving matter; in which some useful results were recorded in databases [16]. Using the database and other reasoning procedures can update their characteristics including their weight coefficient which is used as a basis of the KMS. This KMS is applied in the updated characteristics as the solution to solve a new similar problem using the application of CBR [17]. Hence, the subsequent risk level assessment, the patient's medical record and the recommended expert treatment can then be stored in a CBR system providing the physiotherapists with expert help. Typically during consultation the physiotherapist carry out a set of analyses regarding the profile and state of the physical state of the patients, their motion data and activities are then entered in the form of a query into the CBR in order to retrieve the recommended rehabilitation programme. As Tan, Li, and Liu [18] explained that this approach was very powerful as it could empower care providers and allowed the sharing of knowledge among the medical team. Such an integrated system could also be used to improve the knowledge acquisition process by recommending guidelines for knowledge based medical treatment and provide a valuable learning environment for physiotherapists where the knowledge sharing and reuse could be achieved.

IV. Knowledge Capture from Medical Expert

The knowledge management system makes use of three main knowledge sources: (i) the motion data collected from the elderly sample population which are Thirty-five elderly people, (mostly female) with ages ranging between 61 and 91, living in dwelling communities and nursing homes in Chiang Mai participates in this study, (ii) the risk levels extracted

from Risk Assessment Matrix [19], and (iii) the knowledge elicited from medical experts in the biomechanical domain (see Fig. 3).

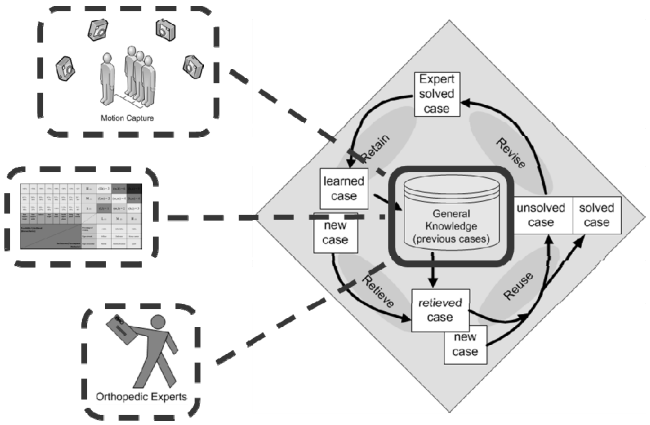

Fig. 3 Three main knowledge sources used in the proposed system.

The knowledge that elicited from the medical experts during his diagnosis using protocol analysis is involving biomechanical, behavioural and profile data used in expert demonstration, will be yielding 38 significant process variables of the KMS for each participant (Table I).

Typically during consultation the physiotherapist will carry out a set of analyses regarding the profile and state of the physical state of the patient, their motion data and activities are entered in the form of a query into the CBR in order to retrieve the recommended rehabilitation programme. A description of the interaction between the CBR components and the physiotherapist and the medical expert is described in Fig. 4.

The treatment elicited from the medical experts provides the physiotherapist with a diagnosis and a set of exercises to be carried out by the patients with their help. A typical description of the recommended rehabilitation programme is shown in Table II. When the new problems encountered by the physiotherapist, cannot be resolved or adapted by the CBR, the information will be compiled and sent to the experts for further review and later included into the library of cases.

V. EXPERIMENTAL RESULT

To retrieve a previous case which is most similar to the new problem from the database, the case based reasoning uses the Nearest Neighbour Retrieval (NNR) to measure the similarity between a target case and a source case [21]. The NNR is a simple technique which has the lowest sensitive to a missing case feature [13]. Although the NNR has a weakness about its retrieval speed, it is still recommended as a primarily technique for CBR.

The procedure of the KMS has been proposed to diagnose the falling risk in elderly people using Motion Capture technology. The implementation procedures of a combination technique within the system are explained as follows:

TABLE I
CBR RETRIEVAL CONFIGURATION (LOCAL SIMILARITY CALCULATION) [20]

Parameters' Name	Local Similarity Function
- Biomechanical Factor (15) Base support length, Base support width, Stride length (R), Stride length (L), Step width, Cadence, Double support phase, Swing phase (R), Swing phase (L), Hip flexion (R), Hip flexion (L), Knee flexion (R), Knee flexion (L), Centre of Gravity (R), Centre of Gravity (L) - Behavioural Factor (1) Percentage of walking - Profile (3) Age, Weight, Height	Interval with Maximum Absoluter of Euclidean distanced
- Behavioural Factor (2) Type of work, Type of exercise - Profile (1) Sex - Healthy/Non Healthy (16) Nerves system, Knees and hip, Joints and backbone, Broken bones, Knees replacement, Hip replacement, Diabetes, Blood pressure, Low blood pressure, High blood pressure, Heart disease, Enlarged prostate, High blood cholesterol, Asthma, Scoliotic, Back surgery	Equal

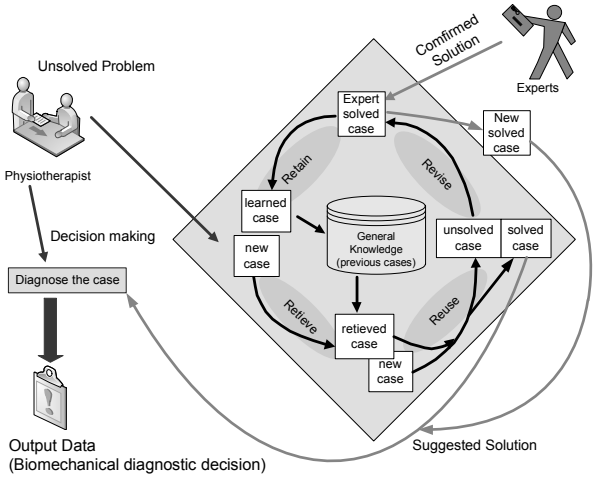

Fig. 4 CBR architecture. [21]

TABLE II
RECOMMENDED REHABILITATION PROGRAMME BY THE EXPERT

Diagnostic results	Descriptions	Examples
Cause assumptions	symptoms sensing at certain areas or organs	Muscle weakness
Treatment	who is the medical expert they need to meet?	Physiotherapist
First aids	the provision of initial care for a falling	Exercise, education, advisory

The CBR approach is adopted to analyse the participant data. This data are imported as input data to the jCOLIBRI2 — back end system—by feeding from the web-based system. This jCOLIBRI2 is a reference platform for developing CBR applications using Java programing language [22]. This input data is identified as new incoming problems for CBR. The CBR retrieves a previous case which is the most similar to the new problem from the database (case base) using NNR calculation. The KMS then finalizes the diagnostic result for the individual in order to give supported information to physiotherapist. Therefore, the physiotherapist can then use the analysis to diagnose recommended procedures and appropriate treatment.

Due to the limitation of the sample data fed to CBR, this study uses Precision, Recall and F-measure indices, which are three most widely used methods in Information Retrieval [23], to evaluate the CBR performance. Although the precision (P) is the fraction of retrieved documents that are relevant, it can be seen as a measure of exactness or quality (Fig. 5). Whereas recall (R) is a measure of completeness or quantity which can be calculated as the fraction of relevant documents that are retrieved.

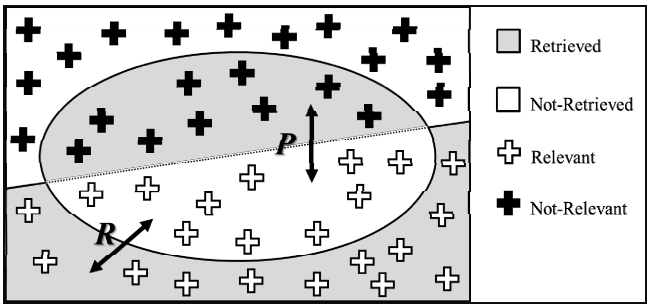

Fig. 5 Precision and Recall

Therefore, this study evaluates the prototype system based on 1) Assumption Attribute category of the cases, and 2) Assumption Attribute category of the cases with K_{NNR}=3 (see Table III).

TABLE III
EVALUATION RESULT BASED ON ASSUMPTION

Assumption	Results		
	Precision	Recall	F-measure
Attribute category	0.5869	0.5869	0.5869
Attribute category with K_{NNR}=3	0.8095	0.1972	0.2997

Although the result interpretations of high in precision means more relevant results are returned by the prototype system than the irrelevant results, high in recall means most of the relevant results are returned by the system [24], and high in F-measure means there are reasonably high value in both precision and recall [25], this study evaluated the performance of the prototype system with a restricted numbers of sample participants. Therefore, the average performance results of the system were shown only 58.69% of precision, recall and F-measure when evaluated with the Assumption Attribute category criteria using K_{NNR}=No. of each category members. The performance of the system was improved to be 80.95% of precision when evaluated with the Assumption Attribute category criteria using K_{NNR}=3. As a result, using too small number of retrieved cases for evaluation leads the performance of recall and F-measure were reduced to be 19.72% and 29.97%, respectively.

In order to complete the procedure of knowledge management, the End-User Computing Satisfaction Instrument (EUCS) [26] is used to evaluate two groups of users; 1) medical experts, 2) clinician and physiotherapists by using structured interview and questionnaire. This KMS-EUCS emphasises on an evaluating the system about the content, accuracy, format, ease of use, timeliness, personalisation, community of practice (CoP), and overall satisfaction. The usage of prototype system based on the discussed criteria in questionnaire is scored and showed in Table IV.

This questionnaire contains the score range from one to five marks for each topic. In Table IV, the average satisfaction showed the highest score at 90.60% from the physiotherapists and clinicians. The comparison in each scenario can be shown in Fig. 6. Both of the user groups were mostly satisfied with the community of practice scenario at 97.50%. Therefore, the prototype system was a success to drive the KM environment among the users by acquiring the medical knowledge from the medical expert and disseminating it to the physiotherapist and clinicians. However, the satisfaction about accuracy scored by the domain expert was the lowest. Most sample data will increase the reliability of the prototype system which can be tested in a further study. In other word, the mechanism of the system was very good in performance, but there was just only lack of case base size that reduced the reliability of the system which could be collected into the database in the future.

TABLE IV
RESULTS OF USERS' SATISFACTION

Scenario	Scores	
	Domain Experts	Physiotherapists and Clinicians
Content	3.5000	4.5000
Accuracy	3.0000	4.7500
Format	3.7500	4.3750
Ease of use	4.0000	4.3750
Timeliness	3.5000	4.6250
Personality	5.0000	4.2500
Community of Practice (CoP)	5.0000	4.7500
Overall	4.6000	4.6500
Average	**4.0437**	**4.5343**

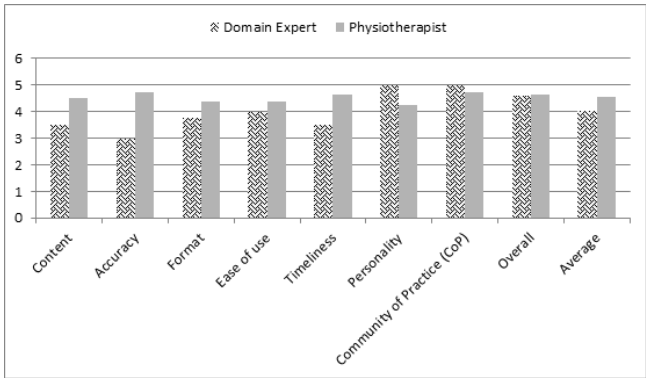

Fig. 6 Comparison graph of users' satisfaction

VI. CONCLUSIONS

This proposed system was designed to assist physiotherapists to make a diagnostic decision using medical expertise and heuristics knowledge provided by medical experts. The idea is to combine KMS technique and motion capture system together as a decision support system. This DSS is created by the application of case based. This system includes all the diagnostic processes in one system. The diagnosis information being derived from the process of screening system provides the result for physiotherapists. They can determine serious falling risks that the elderly are likely to have and provide necessary guidelines for medical treatment.

According to the KMS performance, the Assumption Attribute category criteria with K_{NNR}=No. of each category members result in a fair performance with 58.69% of precision, recall and F-measure. However, when the Assumption Attribute category criteria with K_{NNR}=3 is applied, it performs a better performance with 80.95% of precision, but the scores of recall and F-measure are reduced to be 19.72% and 29.97%, respectively, due to the small value of retrieving case index (K_{NNR}).

Owing to the knowledge management system evaluation, the practitioners give good responses when receiving the expert's knowledge as shown in Table IV. This conveys a positive usage of knowledge representation. The adaptation of CBR enhances the mechanism of knowledge management because it is an effective tool for eliciting the knowledge from the medical expert and then disseminates the useful knowledge to the practitioners, physiotherapists, for example they can use the knowledge to support their decision before providing the appropriate treatment programme to their patients.

The result of KMS-EUCS shows that there is a high satisfaction from the users. The community of practice scenario particularly showed 97.50% of satisfaction. This can confirm the successful of KMS approach within the falling risk screening procedure.

Though the current database includes a limited set of cases, the feedbacks from the physiotherapists are very positive and helpful. The experimental study can be extended to involve more patients and allow experienced physiotherapists to share their experience through the knowledge management system. This can also be eventually used as a training system for the physiotherapist students.

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