Implementation of Case-Method Cycle for Case-Based Reasoning in Human Medical Health: A Systematic Review

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Background of using CBR

Reference	Challenges	Goals	Reasons of Using CBR
[7]	Complex patient situations make rule-based systems for the decision support system for medical diagnosis did not reliable. Knowledge acquisitions for medical diagnosis systems had a challenge for explicit knowledge because the systems were not suitable for the physicians. Besides, for tacit knowledge, the physicians may have not complete knowledge that can be used for the systems.	Designing a template case store using the knowledge-based system and using a case-based system for it.	To cope with the complex patient condition and did collaboration reasoning with others module by using distributed agents.
[8], [9]	Bolus insulin calculator has been shown to be effective in assisting the management of the condition. However, this calculator would always produce the same result from the user's inputs unless specific settings such as the carbohydrate-to-insulin ratio (CIR) and insulin sensitivity factor (ISF) are altered, a process often guided through clinicians. Furthermore, the current patient situations were not taken into account because the system must require specialists for defining the case representation.	Using CBR and sequences of continuous temporal cases that are linked to each other and can be merged into a singular case called an episode for improving bolus recommendations automatically.	To mimic human (experts) behavior for determining the bolus dose.
[10]	Medical emergency decision making could be a challenging task, particularly during mass gathering events. In mass gatherings, when a crisis occurs, medical emergency decisions are usually made under time pressure.	Developing and evaluating a Domain Ontology for Mass Gatherings (DO4MG) with a focus on medical emergency management.	To cope with the complex patient condition and emergency mass situation
[11]	The rule-based approach is challenging to be compiled for complex experience rules. It is also not intuitive. Steps for determining which cases address problems most similar to the current problem	Designing workflow-based CBR System for Clinical Decision System for TAVI	In the clinical field, CBR has explicitly been used in successful CDSSs.
[12]	Word segmentation in Thai is complicated because the language does not have any explicit word boundary delimiters, such as space, to separate adjacent words.	Designing a system that convenient to the users. The system was expected to reduce the expense and the time of hospital visits.	CBR takes advantage of prior diagnosed cases. Each previous case consists of a problem description (symptoms and details) and its solution (disease diagnosis).
[13]	Existing assessments are mostly static, and less consider integrity and dynamic nature of elders' life activity and their health multi-dimension. Single-case-library CBR system has low intelligence level, poor coordination, and limited capabilities of assessment decision support, since CBR assessment only considers single-case library reasoning, and is limited within some particular health status (elders' chronic diseases and psychology).	Develop Collaborative Case-Based Reasoning (CCBR) and apply it to multi-case library resource sharing and knowledge reuse in EHA process.	To cope with the complex patient condition and take advantage of prior patient behavior.

Reference	Challenges	Goals	Reasons of Using CBR
[14]	The number of medical experts is not enough for the increasing numbers of elderly population and this could have serious consequences soon. On the other hand, healthcare organizations have begun to lose this valuable knowledge as the experts are often retired.	Solving the urgent problem by reducing the demand of the medical expert with the trained physiotherapist by applying a Knowledge Management System (KMS) to diagnose falling patterns in older adults using Motion Capture Technology.	The relationship between CBR and KM is evidenced in plenty of publications and books.
[2]	The complexity of decision-making, especially in medicine and public health, comes from the uncertainty knowledge, facts, and used language.	Illustrating the use of CBR adapted to search optimal medication or treatment from similar clinical cases, to improve the knowledge representation and the generation of medical ontologies at each stage of the clinical process by combining MAS and CBR. The study was expected to support formal reasoning of medicine and related fields.	CBR is analogous to problem-solving, which memorizes and restores experience data to solve similar cases.
[15]	Clinical experience and cases cited in the literature have identified that it is often challenging to motivate people who have had a BI to engage in the repetitive exercises common for rehabilitation, so games are used to help make repetitive tasks fun and engaging. Therapists had difficulty finding pertinent information about the games; i.e., data to guide the selection of appropriate and therapeutically effective games in an environment of rapidly increasing games.	Creating and evaluating a prototype. It is aimed at helping therapists select appropriate games for their patients who have had a BI that matches their therapeutic goals and individual patient attributes. Maximizing the use of COTS games in BI rehabilitation through the creation of a decision tool for therapists that uses a Web-centric knowledge-base of COTs use in BI therapies.	Because of the complexity of the problem and solution spaces, the traditional rule-based method was not going to work for BI decision tool. Authors structured the knowledge-base as ‘cases’ and adopted case-based reasoning (CBR) methodology.
[16]	Designing the dietary menu planning is a complex task. It consists of several constraints.	Modelling domain ontology of Malaysian food composition.	Automatically adapt the old design solution
[17]	The problem domain should be well understood and custom when using rules for reasoning. Rules cannot cope with complexity and the evolution of knowledge. Meanwhile, CBR is less efficient at first used because of the lack of cases.	Designing a medical platform for CDSS using hybrid reasoning-based	To cope with the disadvantages of both rule-based reasoning and case-based reasoning.
[18]	Knowledge sharing and transfer at different location and situation that faces a dynamic environment system need many constraints. Meanwhile, knowledge-in-practice-context is more useful.	Modeling context-aware for supporting clinical knowledge sharing across organizational and geographical boundaries in ubiquitous e-health. This model was expected enabling clinicians in disparate locations to gain a common representation of relevant situational information in each other’s work on the notation of practices.	To cope with case-situation and case environment an to adapt clinician problem-solving in the real situation: having previous knowledge(case, location, solution, overcome), adjusting, and applicating.
[1]	Telemedicine benefits from an extensive bibliography but practical challenges remain: organizing the management of the knowledge wealth, improving security engineering and risk management in the context of continuous improvement of healthcare services.	Developing a telemedicine framework with knowledge engineering using taxonomic reasoning of ontology modeling and semantic similarity.	To support the formalization of reasoning procedures for collaborative medical acts in telemedicine.
[19]	Explicitly making design suggestions for all kinds of product design is not easy because behavior change involves various psychological and social factors	Applying method (CBR and Persuasive Technology) for facilitating product design that persuades users to have more bodily movements for both health and energy harvesting by using concepts of case-based reasoning.	CBR is helpful because CBR properly retrieves past successful cases and getting useful suggestions.
[20]	Time and money for visiting the clinic for both patients and physicians were much for doing a consultation.	Developing a Diabetes web application for patients, doctors, and former patients as a recommendation system, e-learning tools, and glucose level model.	CBR provides automatic recommendation like human reasoning from the patient based on recorded data and physicians preferences that contain the physicians’ habit and knowledge about Diabetes. CBR makes cases well defined than using the rule-based system.

Details of Used Knowledge

Reference	Medical Health Field	Knowledge	Knowledge Dimension
[7]	Medical Case Store	Explicit - medical literature or public sources, and augmentation knowledge model (such as available causal models, prototypes, or guidelines).	Multi knowledge
[8], [9]	Type 1 diabetes	Explicit knowledge: medical literature and bolus calculator applications	Single Knowledge
[10]	Medical emergency management for mass gatherings	Tacit Knowledge. Capture with focus group technique involved 10 participants from different emergency management related organizations. The selection of the participants was based on their research, domain knowledge, publications and professional experience in the area of mass gathering medical management in Australia.	Multi Knowledge
[11]	Transcatheter Aortic Valve Implantation (TAVI)	Explicit: documents of 82 patients operated at Rennes University Hospital is used as TAVI case base.	Single Knowledge
[12]	50 elementary diseases	Explicit knowledge from health records (descriptions of symptom and solutions: disease and remedy)	Multi Knowledge
[13]	Elders Health Assessment System	Tacit: captured using the Delphi method.	Multi Knowledge
[14]	The health care issues of the elderly affected by a fall in Thailand.	Tacit Knowledge that was captured from medical experts with interviewing, and tracking the reasoning process.	Single Knowledge
[2]	Gastric cancer, breast cancer, acute diarrhea, addiction, antibiotics, and infectious diseases	Explicit knowledge	Multi Knowledge
[15]	Brain Injury Rehabilitation	Tacit knowledge captured by interviews, observations, paper-based diary studies with therapists.	Single Knowledge
[16]	Dietary menu plan for diabetics	Explicit Knowledge: food nutrient composition book and food atlas. Tacit knowledge that was captured from Universiti Kebangsaan Malaysia Medical Center (UKMMC).	Single Knowledge
[17]	A lot of diseases	Theoretical knowledge as clinical rules provided by AHA and ESC (explicit knowledge) and practical knowledge as clinical cases (tacit knowledge) that inputted to the system.	Multi Knowledge
[18]	A lot of diseases	Both explicit and tacit knowledge. Tacit gained from existing cases and clinician knowledge that inputted to the system.	Multi Knowledge
[1]	Oncology case	explicit: from the description of collaborative practices	Single Knowledge
[19]	Health product design	Explicit using literature to define categories that used to users based on: target behavior involving bodily movements, Motives and lack of ability of users, Design principles modified from the list in PSD, Design techniques modified and extended from the list in DwI method, and Technology (hardware) used for effective persuasion. Then, 98 cases were collected from Yanko designs, Gizmag and Inhabitant that introduce a new product, fitness products and other ingenious designs from modern designers.	Single Knowledge
[20]	Diabetes	Explicit knowledge: medical record; Tacit knowledge: patient information about their recorded diseases and their treatments from physicians and the physicians' preferences.	Single Knowledge

Implementation of CBR

Reference	Case-Method Cycle	CBR steps	Evaluation Technique
[7]	Case library development process: ontology-based relations (virtual case base, which can store cases temporarily or permanently based on the privacy requirement). System operation process: Distributed CBR architecture. Database mining process: Reasoning ontology (semantic reasoning) Knowledge transfer process: by API to interact with other modules		

Reference	Case-Method Cycle	CBR steps	Evaluation Technique
[8], [9]		Retrieve: A temporal sequence is used to describe both new problems and previous cases. Researchers described the technique on the paper. The Euclidean distance function had been adopted for determining similarity Reuse: The reuse step adopted a simple strategy of averaging the bolus prediction of the retrieved cases. Retain: The new solved case retained to the system.	
[10]	Case library development process: 201 records of different mass gathering events which were collected by St John Ambulance Australia personnel (St. John, 2010) saved on ontology and database. Database mining process: jCOLIBRI2 framework3 in Java. Ontology-based CBR systems by using the Onto-Bridge4 libraries. Management process: using Leximancer - a computer-assisted text analysis application - to extract management process concept for the system based on 'Mass Gathering Compendium' collected by Arbon and the Emergency Management Australia Manual 'Safe and Healthy Mass Gatherings', 1999, Part III, Vol. 2, Manual 2.	Retrieve: User inputted patient condition with existing attributes. Then that condition estimated patient presentation rate (PPR) to the similar events in the past.	Implementing a case-based reasoning decision support for emergency medical management in mass gatherings. The criteria-based evaluation includes the refinement ofDO4MG according to the domain experts' feedback. Application specific evaluation of DO4MG details the overall architecture for intelligent decision support in mass gatherings and an illustration of the case-based reasoning prototype developed to test its usability.
[11]	Case library development process: Cases saved in CSV form Management process: Work-flow system	Retrieve: the current case is compared with all the past experiences in the case base, and the most similar are recovered. The comparison used local distance and global distance. Reuse: a solution to the current case is determined based on the solutions found in the retrieved cases, which are mapped to target the actual prob- lem. This may involve adapting the solution as needed to fit the new situation. Revise: revise by human (clinicians) feedback. Retain: new cases will be temporarily stored in a specific directory until an expert checks them.	probabilistic evaluation approach
[12]	Case library development process: MySQL is used for storing the previous cases in a case base form directly filled by a doctor. Administrator stores the previous cases including descriptions (symptom) and solutions (disease and remedy) into the case base (knowledge base). Not mention the administrator is doctor or not. Database mining process: Using Thai Information Retrieval. Management process: The admin can edit, search, insert, and delete previous case(s). Knowledge transfer process: Via The proposed system between Patient and Administrator	Retrieve: Using Thai Information Retrieval. Boolean model is used for matching the description of a new case to the previous cases on retrieval of relevant cases. The most relevant or the most similar cases will be retrieved. Reuse: The solutions to these cases are reused based on ranked similarity values to diagnose the disease. Our system will suggest the solution from the retrieved cases, namely the disease and its remedy. Revise: the administrator will check the new case that consists of a query (symptoms) and a solution. Retain: the administrator decide whether to add it to the knowledge base.	the 30 user queries and their correct answers were formulated to test the system. The evaluation of the proposed system is based on precision

Reference	Case-Method Cycle	CBR steps	Evaluation Technique
[13]	Case library development process: used XML to represent and organize heterogeneous cases in multi-case libraries. System operation process: KGA-NN, JAVA, XML, SQL Server 2000 and DBMS are used Database mining process: used Knowledge-Guided Approach with Nearest-Neighbor (KGA-NN).	Retrieve: define characteristic attributes of a new elder health problem case. Retrieve cases from the library with similarity and take the most similar case and its assessment program. Reuse: Modify and optimize the assessment program, and examine whether it meets the needs of the new case. If it does not meet the needs, continue to modify and optimize to make it more suitable for the new case. Revise: Re-examine and evaluate whether the new case is worth saving. Included add expert knowledge. If necessary, save it in the case library, and retain the corresponding assessment program. Retain: Retain the case and its assessment program.	probabilistic evaluation approach
[14]		Retrieve: 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 because NNR is a simple technique which has the lowest sensitive to a missing case feature but has a weakness about its retrieval speed.	this study uses Precision, Recall and F-measure indices to evaluate the CBR performance. This study evaluates the prototype system based on: Assumption Attribute category of the cases, and Assumption Attribute category of the cases with KNNR=3.
[2]	Case library development process: Cases stored in the database through case indexation module. Cases were modeled as objects to build system knowledge. All cases were stored as object cases records. System operation process: UML (Unified Modeling Language) notation was used to express semantic relations defining the terminologies of domain knowledge. Database mining process: The case retrieval module used the database of indexed object cases and distance to evaluate the degree of partial structural similarity between stored cases and new cases being processed. The retrieval concept used natural language processing.	Retrieve: Physicians inputted patient's condition through the user interfaces. Then, the patient's history was extracted from patient records. This information was defined as a new case. CBR computed its component similarities by exploring indexed knowledge. CBR seeks to identify the clinical evidence with essential words such as terminologies and their synonyms, as well as adjectives, and verbs that make the phrase more precise. MAS filtered out the unnecessary treatment suggestions by taking into account some elements such as medication allergy, medication side effect, coexisting disease, and complication.	Domain experts were involved in providing feedback on accuracy and used probabilistic evaluation approach.

Reference	Case-Method Cycle	CBR steps	Evaluation Technique
[15]	System development process: Usability studies of a "Choose a Game" interface. The backend coded in Java algorithm and built a responsive interface using the Bootstrap framework. Database mining process: The algorithm that was used was nearest neighbors for case retrieval and weighted average to assess similarity. The initial weights were set based on our assessment of the importance of the case attributes. Management process: Using user-ddriven approach Knowledge transfer process: Therapists feedbacks captured by interviews. Their feedbacks then used to modify the prototype.	Retrieve: The system asked only for patient attributes found important for game decisions in the preliminary studies or goal matches that were decided by therapists. Then, therapists were presented with a summary list of games and their information: cover art, summary game information, information about how well the game matches to the input case (five-star overall match and match to the top therapeutic goals) and comments about the games from therapists. Beside those, the information is the game's required movements, the game's rated effectiveness at all goals, and a gameplay demo video. Reuse: Patient used the prototype and therapist accompanied the patient. The therapist also gave feedback for the prototype while the therapy session. Revise: Authors examined the cases in the knowledge-base. They examined the differences in games' effectiveness at addressing top therapy goals and the differences in perceived enjoyment in the therapy sessions among the eight patient play personality types. Retain: The feedbacks from therapist stored in the system	The prototype evaluated through user studies with 29 therapists at two rehabilitation hospitals. The prototype through user studies with 29 therapists at two rehabilitation hospitals. The evaluation test protocol included a short training session with therapists. Each study period was followed by a brief interview or survey to explore user interface issues and usefulness of the feedback information and recommendations.
[16]	Case library development process: Ontology 101 Database mining process: Reasoning ontology (semantic reasoning)	Retrieve: Knowledge Intensive Design Case Adaptation: Constraint-based method that general to the domain using semantic technology. Revise: revise by experts Retain: permission by experts	Evaluation is done by testing ontology in the application.
[17]	Case library development process: Using ontology that involved Electronic Health Records. Database mining process: Using Information Gathering System that used questions that dynamically adapt to the patient profile.	Retrieve: Using semantic-web rule engine that guided by Ontology for RBR and Ontology for CBR. Reuse: The retrieval result then assigned to clinicians, and the clinician determined the right case would be used. Revise: The adapted case with its solution and outcome revised or validated with the same clinician or superior clinician. Retain: Case stored. If no case at retrieval step, used case from RBR.	The clinician did an evaluation or revise step.
[18]	System development process: Consist of User Interface Layer, Cross-boundary collaboration layer, and Practice-centered Awareness Manger. Case library development process: Using RDF (Ontology) System operation process: Using CaDHealth architecture that consists of client side, server, backend, external, and cloud-based services. Knowledge transfer process: Using a firewall to ensure sensitive patient information.	Retrieve: By retrieving the cases and their work practices instance that match new cases and work situation by reasoning mechanism in CBR research community.	Evaluation is done by comparing the result of using system and human.

Reference	Case-Method Cycle	CBR steps	Evaluation Technique
[1]	Case library development process: cases saved in CSV format. Database mining process: using ontology at Protégé 3.5 and MyCBR.	Retrieve: Using similarity to the patient medical record and the existing cases and treatment. After that, added the evidence similarity to that treatment. Experts' opinion can confirm these points. Reuse: reused that treatment with some adaptations depends on age, potential drug interactions and allergies. Retain: Registered by the type of diseases	
[19]	Case library development process: an information system based on data management software ACCESS. Database mining process: using ACCESS	Retrieve: Client input their target behavior of the product. They can also input the motives and ability of target users that will use their product. The system then suggests 2 type mode: inspiration mode and prescription mode. In inspiration mode, retrieved case profiles are used to inspire designers, while in prescription mode, suggestions on design principles and techniques and applicable technologies appeared in retrieved cases are summarized and deliberately presented for stimulating new design ideas.	
[20]	Case library development process: Cloud Database: Microsoft Health Vault; Local Database: MySQL System operation process: System was operated with 2 sides: patient side and physician side Knowledge transfer process: Using an online platform that can be accessed from mobile and desktop.	Retrieve: Retrieval step will be processed by using JColibri system. The system will compare the new case to existing cases and sent the recommendation to the patient via inbox mailing system. Besides the recommendation, the medical team also can suggest the recommendation. The system used the Grammatical Evolution (GE) algorithm using patient data.	

Limitation and Future Research

Reference	Limit	Next Research Suggestions
[7]	Although the reasoning process is not the focus here, the reasoning module will still be depicted for completeness.	Design the case distiller and develop a prototype for constructing cases
[8], [9]	The selection of features, algorithms, and weights was not evaluated in various case bases in other domains or experts.	Explore the use of different algorithms, and explore how the algorithms used in this research performed in other domains.
[10]		constructed multi knowledge and health fields ontology and develop a mobile application.
[11]		revise by human (clinicians) feedback.
[13]		The prototype system is too simple and the data is small. Future researches will focus on developing a well-functioned CCBR-EHA experimental system and make the retrieval experiment with massive data.
[14]	Focus at transfer knowledge from the experts and retrieve them.	The study can be extended by involving more patients (adding more cases).
[2]	Data flow that was used: diagnosis, prognosis, treatment, and therapeutic monitoring.	
[15]	The sample size for most games is too small to infer how well the games met any particular goal. The CBR algorithm was still immature in authors opinion. The case knowledge-base relied completely on subjective measures.	
[16]	Focus phases: build-evaluate-revise life cycle	evaluate this study in the future.
[18]		Incorporating and validating the approach in a real-world healthcare setting.
[1]	Limited on application area and purpose in telemedicine taxonomy	Improve the framework and build it to be accepted by all stakeholders.
[19]	The contribution of this work is to identify and provide design suggestions for specified target behaviors and target users with the help of a case library	
[20]		Optimizing HTML5 modules and validating the system to hospitals.

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