Ontology Development in Patients Information System for Stroke Rehabilitation

*Radhi Rafiee Afandi[1], Abduljalil Radman[1], Mahadi Bahari[2], Lailatul Qadri Zakaria[3], Muzaimi Mustapha[4] and *Waidah Ismail[1]

Faculty of Science and Technology, Universiti Sains Islam Malaysia, Negeri Sembilan, Malaysia[1]
Department of Information System, Universiti Teknologi Malaysia, Johor, Malaysia[2]
Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, Selangor, Malaysia[3]
Department of Neurosciences, Universiti Sains Malaysia, Kelantan, Malaysia[4]

ABSTRACT

Disability of upper limb parts is common for stroke survivors. Early implementation of well-organized upper limb treatment after stroke may result in fast recovery of upper limb functions. There are many treatments and assessments to improve the ability in upper limb movements. However, the specialists in rehabilitation departments use patient information system (PIS) to store and manage all the patient's information and assessment records. The information and assessment records of the patients usually are obtained from various categories of assessment but it is inconsistent. This causes difficulties in seeking information, and needs to run all the assessments even those not important for the patients. In this paper, an ontology in the development of PIS will be constructed to overcome the problem. The ontology enables semantic knowledge representation for upper limb stroke rehabilitation. This ontology will be designed based on the Enterprise Ontology, TOronto Virtual Enterprise Ontology, METHONTOLOGY and Ontology Development 101. As a result, the proposed ontology will improve the information management in PIS.

Keywords: Upper limb stroke, ontology, rehabilitation, Patients Information System (PIS).

1 INTRODUCTION

Improving upper limb functions is an essential for stroke patients because upper limb is the most effective part for stroke survivors (Ramírez et .al, 2015). The specialists in rehabilitation departments have their responsibility to provide the specific assessments for the stroke patients' recovery. As we know, all the patients' information and assessment results are recorded to the Patients Information System (PIS). Currently, PIS still use relational databases for storing the data. The drawbacks of relational databases are that is shown only when request a query, and the semantic description of the database is represented using its schema only (Hohenstein, 1996). Result of this, ontologies have appeared as an alternative to relational databases in order to improve the performance of PIS (Abas et. al., 2011). However, ontology-based systems in rehabilitation department will help the specialists to easily manage the patient's information and assessment records.

Ontology is a way to transfer information or knowledge about something domain (Roussey et al., 2011). Ontology is built as a representative of knowledge background in a domain. In addition, the ontology is built for enabling the effective sharing of information (Fonseca, 2007). Information in ontology must be confirmed by a specialist domain, and can be extend and useful if shared with various parties. The important process of developing an ontology is to identify goals and scope, build, evaluate and document the ontology (Uschold & Grunninger, 1996). Related to this, ontologies can assist in PIS design by providing a comprehensive model of the information and process need for healthcare delivery (Fonseca, 2007). However, few researches has been done in developing an ontology for PIS to represent the domain area of stroke rehabilitation. In this paper, we will explain about the development of an ontology for upper limb stroke rehabilitation in the PIS.

The remainder of this paper is organized as follows. Section 2 explains about methodology for the development of ontology including the design of the ontology and as well as the PIS framework. Finally, Section 3 concludes our final clarifications and future work.

2 METHODOLOGY

In the development of ontology, there is no specific methodologies (Smith et. al., 2007), as evidenced by various methodologies from the literature which employed in many projects. In this paper, the methodology for implementing an ontology in PIS was adapted from (Ohgren & Sandkuhl, 2005) which employs the Enterprise Ontology, TOronto Virtual Enterprise Ontology, METHONTOLOGY and Ontology Development 101. This methodology is suitable for small and medium scale applications (Ohgren & Sandkuhl, 2005). The advantages of this methodology are to reduce the development time and effort to meet the specifications of PIS. The methodology was divided into four phases: requirement analysis, ontology development, implementation, evaluation and

* To whom correspondence should be addressed: radhirafiee@raudah.usim.my and waidah@usim.edu.my

maintenance. Each phase of the ontology development is used for the next phase. The illustration of this methodology is shown in Fig. 1 that also shows the results of each phase.

Phase 1: Requirement Analysis
This phase is to analyze the needs of developing ontologies. In the process of developing an ontology, there are few things to note:
1.What is a domain that ontology used?
2.Why this ontology should be built?
3.What are the problems that exist in the selected domain?
4.Who will use this ontology?
5.What is the scope of ontology?

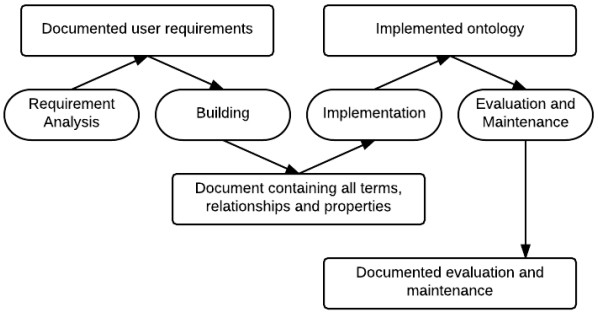

Fig. 1. Ontology development methodology [12].

After analysing the Clinical Data Proforma from Hospital Universiti Sains Malaysia (HUSM), the objects to build up the ontology are created. Table 1 shows 10 tangible objects were created based on HUSM's Proforma form. These objects were set as individuals or objects that serve as the basis of determining the classification in ontology development.

The methodology to define the concepts and relationships is a middle-out approach which began with the important concepts and made precise generalizations or specifications. The basic concept should be identified first and used to drive the development process of ontology (Domingue & Anutariya, 2008). This begins with a look at the common features for the tangibles as a function of the object to form class and relationship between classes. To facilitate the definition of class, things are divided into small groups, so the similar characteristics of the things are studied carefully. Accordingly, the things were placed in the same class according to the similar characteristics.

Table 1. Tangibles in Proforma

No.	Things
1.	Physician
2.	Therapist
3.	Nurse
4.	Minimum data
5.	Clinical
6.	Diagnosis
7.	Management
8.	Supplementary
9.	Care planning
10.	Score ranking

Next, we use the top-down approach which identifies the common class relating to the classification of objects that defined before. This ontology is divided into six main categories: specialist, patients, proforma, session, therapy, and follow up.

Phase 2: Ontology Development
This Ontology will be developed by using Protégé version 5.2.0. This Protégé is an open source and developed by the Stanford Center for BioMedical Informatics Research. It was supported by the National Institute of General Medical Sciences. In this platform, we will build up a domain and application model based on the ontology knowledge. Protégé made it possible to build an ontology in Ontology Web Language (OWL) with an efficient and easy way, and to access, edit and use the existing ontology (Lozano-Rubi et. al., 2014 & Knublauch et. al., 2004). The steps taken to develop the ontology is as follows:

1. Create classes: all classes or subclasses are under the *Thing* class in Protégé. This will show the class hierarchy for each category that was identified during the process of defining the concepts inserted in the Protégé.
2. Create properties: the properties are divided into object properties and data properties:
   a. Object properties: connect between two objects or instances.
   b. Data properties: connect one instance of the literal kind of data Extension Markup Language (XML) schema or the Resource Description Framework (RDF) literal attribute owned by the object or instance.
3. Create Individual: lists of tangible objects were inserted in the Protégé as individual. The number of tangible objects increase from time to time based on the data given by HUSM.
4. Insert the literal value for each individual.

Fig. 2 shows the design of the ontology for the whole part of classes and the tangibles. It shows the relation of that classes with the other classes as well as the relation between individuals inside each class and other individuals. Based on this design, the specialist (i.e. physician, therapist, and nurse) have an access into PIS to monitor and insert the patients' information based on the assessment results.

In proforma, the initial information of the patients is inserted during the first day of their admission in the rehabilitation department. This information is regarded the minimum data. The main part of this ontology design is the session of the

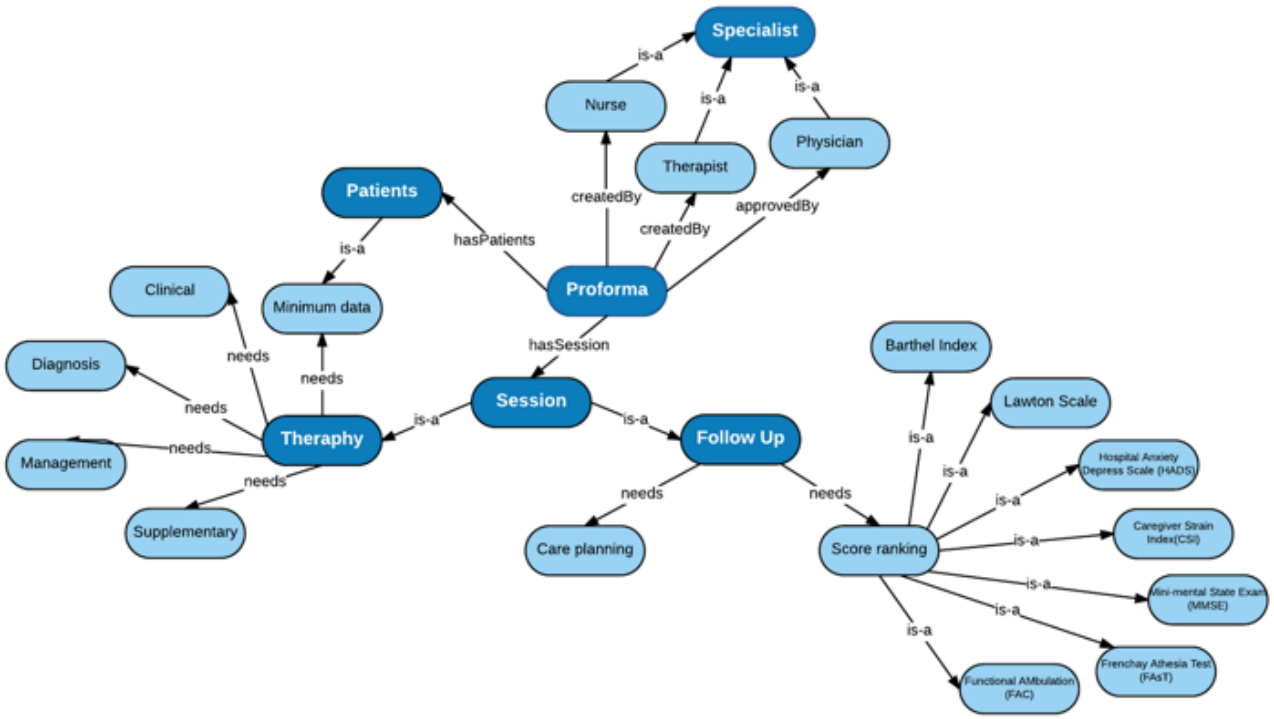

Fig. 2. Ontology design for PIS

patients for their weekly assessment (i.e. therapy and follow up assessments).

Therapy assessment includes the class of clinical, diagnosis, management and related information data from the assessment that run by each stroke patients. While for follow up assessment, patients need to come back to the rehabilitation department in order to run other assessments that include assessment for care planning and score ranking.

In addition, the validation and improvement of this ontology is needed. This process is correcting errors in the classification and the object based on the requirements (i.e. Clinical Data Proforma) given by the domain experts. The relationship between the class and individual also needs to be revised so that there is no error in reasoning process. Improvements are also possible if there are any updates in the list of objects that are registered as tangible objects in Proforma. Among the possible errors is the literal value of individual properties data. The domain expert is required to validate the inserted data so the reliability of ontology development is high.

For the ontology testing and maintenance, the tests will be performed by the user and based on the PIS prototype. Result of this process can predict the perfection of the development of upper limb stroke ontology. This is crucial for ensuring a proper classification or category for each object, including the relationship between the concepts of the ontology. Feedback from the users on the prototype will be recorded for improving the ontology design.

Phase 3: Implementation (Developing a User-interface for Testing)

The analysis will be conducted based on PIS prototype through the testing made by users. The prototype system is needed to send the user's query in SPARQL form. PIS prototype will be develop to test and verify the usability and validate the objectives and scope of the designed ontology are achieved. PIS is a web-based application and it will be develop using PHP language and JavaScript. To access the information on this ontology is via RDF/XML format. Therefore, some of the Javascript semantics libraries will be used (i.e. jOW and jQuery) to allow an access to the RDF/XML file format. In addition, Netbeans Integrated Development Environment (IDE) will be used as a platform for developing the prototype interface. The proposed ontology will be stored in RDF/XML file format. Fig. 3 shows the framework of the PIS prototype that will be created based on the guidance of previous studies about SPARQL query processing (Samreen et. al., 2013 & Malik et. al., 2012) and OWL files (Lozano-Rubi et. al., 2014).

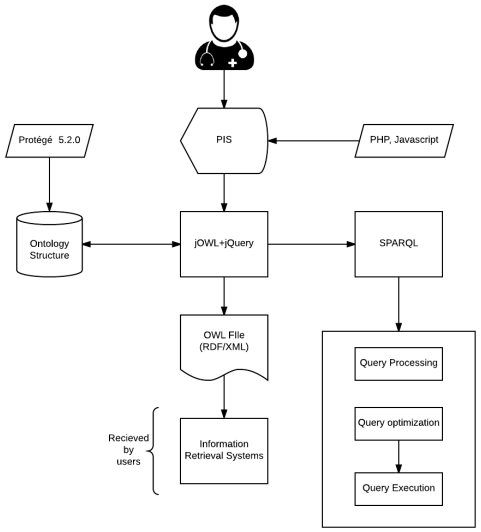

Fig. 3. PIS prototype framework.

other categories. Besides, it shows the instances of the clinical data that is "Handedness" and "Flu vaccination".

Phase 4: Evaluation and Maintenance
The testing process towards the perfection and usability of ontology data will be using PIS prototype. The prototype will be tested and evaluated by 10 specialists in Rehabilitation Department at HUSM.

3 CONCLUSION AND FUTURE WORK

We have presented an ontology design for implementation in PIS at Rehabilitation Department, HUSM. The ontology includes the key factors acknowledged through a requirement study and also review the previous research paper. With the proposed ontology in this paper, we aim to facilitate the specialists in order to manage the information including the patients' assessments. We also aim at sharing and integrating this knowledge with other ontologies. As a future work, we

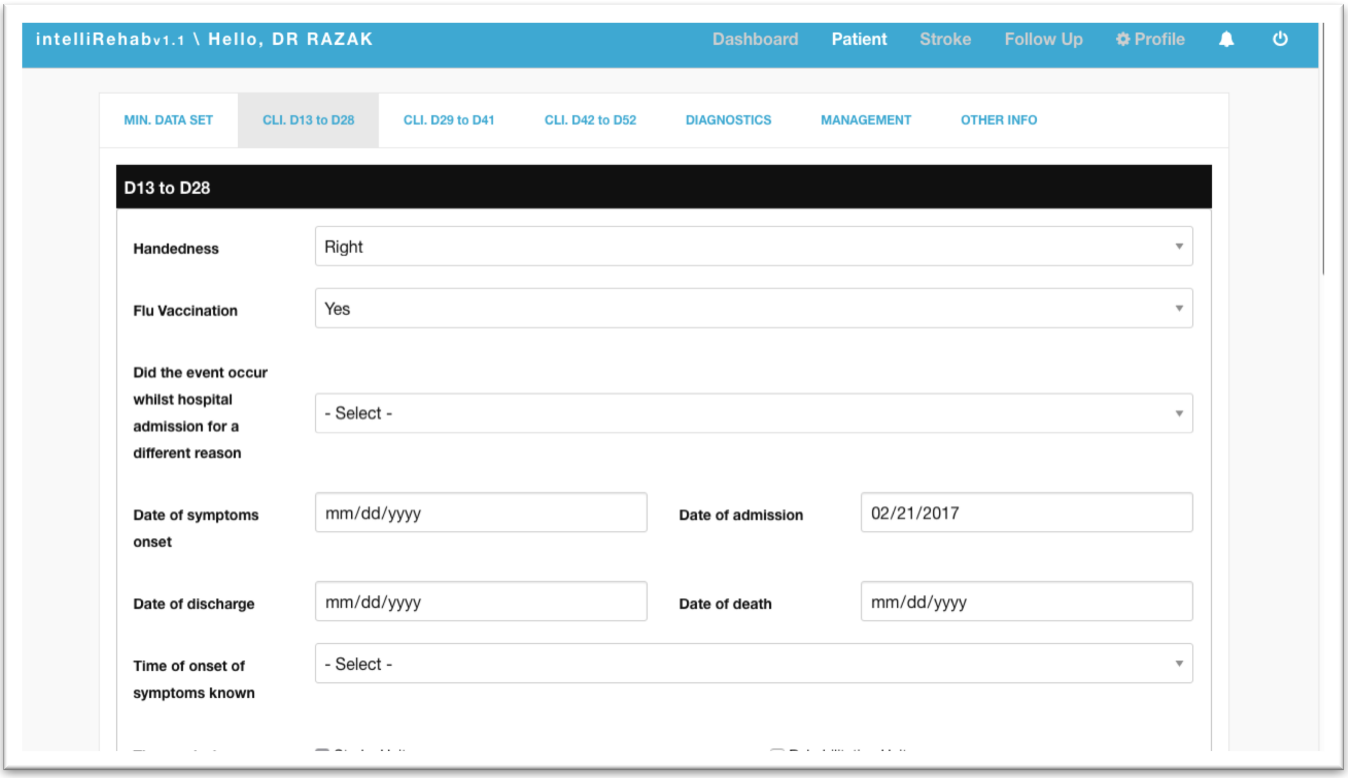

Fig. 4. The interface of the category in therapy assessment

The first interface design of the PIS system prototype is shown in Fig. 4. It shows the classification of the category that is created based on the tangible objects. These tangible objects (i.e. Clinical, Diagnosis, Management, and Related Information) are placed under the therapy assessment category. The information related to the clinical data displays a therapy assessment and the relation of this category with

will continue the implementation and evaluation of the proposed ontology in PIS. This evaluation will deal with the specialists to validate the usability of the PIS in stroke rehabilitation department.

ACKNOWLEDGEMENT

Authors wish to thank all participants who participated in the study. This research is funded by NEWTON-UNGKU OMAR FUND via international grant research with code USIM/INT-NEWTON/FST/IHRAM/053000/41616. Finally, thanks to Hospital Universiti Sains Malaysia (HUSM) for the contributions in this project.

REFERENCES

Abas H.I., Mohd. Yusof M., and Mohd Noah S.A. (2011). The application of ontology in a clinical decision support system for acute postoperative pain management. International Conference on Semantic Technology and Information Retrieval, STAIR 2011.

Avison D., and Young T., (2007). Time to rethink health care and ICT, Commun ACM;50(6):69–74.

Berg M. (2003). The search for synergy: interrelating medical work and patient care information systems. Methods Inf Med, 42(4):337–44.

Domingue J. and Anutariya C. (2008). The Semantic Web. 3rd Asian Semantic Web Conference, ASWC, Bangkok, Thailand. Germany: Springer-Verlag Berlin Heidelberg.

Fonseca F. (2007). The double role of ontologies in information science research. Journal of the Association for Information Science and Technology; 58(6):786–93.

Gennari J., Musen M., Fergerson R., Grosso W., Crubezy M., Eriksson H., Noy N., and Tu S. (2003). The evolution of Protégé: an environment for knowledge-based systems development. International Journal of Human Computer Studies, 58(1):89–123.

Hammond W. E., Cimino J. J. (2006). Standards in Biomedical Informatics. In: Shortliffe EH, editor. Biomedical Informatics: Computer Applications in Health Care and Biomedicine. New York, NY: Springer.

Hohenstein, U. (1996). Bridging the gap between OWL and relational databases. ECOOP '96 — Object-Oriented Programming, 1098, 398–420.

Hong K. and Saver J. (2009). Quantifying the Value of Stroke Disability Outcomes: WHO Global Burden of Disease Project Disability Weights for Each Level of the Modified Rankin Scale. Stroke, 40(12):3828–3833.

Knublauch H., Fergerson R., Noy N.F., and Musen M.A. (2004). The Protege OWL Plugin: An Open Development Environment for Semantic Web Applications". Proceeding of the 3rd Int. Semant. Web Conf. (ISWC 2004), pp. 229-243.

Kuziemsky C., Lau F. (2007). A four-stage approach for ontology-based health information system design. 11th Conference on Artificial Intelligence in Medicine (AIME).

Lozano-Rubí R., Pastor X., and Lozano E. (2014). OWLing Clinical Data Repositories with the Ontology Web Language. JMIR Med. Informatics, 2(2):1-17.

Malik S. K. and Rizvi S. (2012). A Framework for SPARQL Query Processing, Optimization and Execution with Illustrations. Int. J. Comput. Inf. Syst. Ind. Manag. Appl. 4:208–218.

Musen M. A. (1999). Scalable software architectures for decision support. Methods of information in medicine. 38(4-5):229–38.

Ohgren A., and Sandkuhl K. (2005). Towards a Methodology for Ontology Development in Small and Medium-Sized. Engineering, no. chapter 2, pp. 369–376.

Ramírez-Fernández C., García-Canseco E., Morán A., Gómez-Montalvo J. (2015). Ontology-based Design Model of Virtual Environments for Upper Limb Motor Rehabilitation of Stroke Patients. Proceedings of the 3rd 2015 Workshop on ICTs for improving Patients Rehabilitation Research Techniques - REHAB'15.

Roussey, C., Pinet, F., Kang, M. & Corcho, O. (2011). Chapter 2: An Introduction to Ontologies and Ontology Engineering Catherine. Dlm. Falquet, G., Métral, C., Teller, J., Tweed, C. (pnyt). Ontologies in Urban Development Projects, hlm. 9-38. London: Springer-Verlag.

Saad S., Salim N., Zainal H., and Muda Z. (2011). A process for building domain ontology: An experience in developing Solat ontology. Proceedings of the 2011 International Conference on Electrical Engineering and Informatics, ICEEI 2011.

Samreen S., Mirza J. S. and Rasheed A. (2013). RDF and OWL Ontology Building of Web Applications. Res. J. Inf. Technology, 5(4):109-117.

Smith B., Ashburner M., Rosse C., Bard J., Bug, W. (2007). The OBO Foundry: coordinated evolution of ontologies to support biomedical data integration. Nature Biotechnology. 25(11):1251–5.

Smith B., Kusnierczyk W., Schober D., Ceusters W. (2006). Towards a Reference Terminology for Ontological Research and Development in the Biomedical Domain. CEUR, 222:57– 65.

Uschold, M. & Gruninger, M. 1996. Ontologies: Principles, Methods and Application. Knowledge Engineering Review, 11(2):93-136.

Whyte J. John L. Melvin N. C. (1996). Functional Evaluation of Stroke Patients. (N. Chino & J. L. Melvin, Eds., 2016). Tokyo: Springer Japan. http://doi.org/10.1007/978-4-431-68461-9.

Zhao C. and Zhang L. (2013). Research of Information Presentation for Electronic Medical Record Based on Ontology. In 2013 6th International Conference on Information Management, Innovation Management and Industrial Engineering, pages 489–492.