A SYSTEMATIC REVIEW OF HEALTH CARE ONTOLOGY

ABSTRACT

Objective: The study sought to extracts information about the steps, methods, techniques, initiatives and strategies that is use in establishing ontology in the medical sector.

Methods: The guideline that was employed for conducting the systematic review in this research work is that which was proposed by (Kitchenham,2007). The Google Scholar, Scopus and Web of science were searched for proceedings from conferences and journal papers between 2009 and 2018. Articles focusing on health care and ontology, health ontology and diagnosis system were selected. The AND operator was used in the Boolean language construction for the article search to limit article presented to those that actually apply Ontology in the Health care. Selected articles were considered eligible base on their studies appropriately fitting into providing answers for the research questions that were presented in this research work within the last 10 years.

Results: 20 research articles were included in the review; of the initiatives of the research works considered, Seven (7) were of Methodology, Two (2) were technique based, Three (3) were Framework based, Two (2) were Process based while Six (6) were extensions of those in existence.

Conclusions: The approaches considered were ontology based in terms of the use of Protégé-owl editor tool, SPARQL, Protégé 4, OWL 2, OWL, RDF, SNOMED CT. The main contributions include but not limited to Modelling of knowledge representation using Protégé for relating data and concepts with references to diabetes diseases, Mobile based health care ontology, classification of diseases based on phenotypes, improvement in service delivery and availability of reliable health data. This Ontology heath care review which was carried out showed the need of Ontology based models to improve health service delivery for both the users (patients) and the care providers.

Keywords: Ontology, Health care, diagnosis system, eHealth

INTRODUCTION

Conceptual information modelling is generally used in expressing the meaning of certain information in applications modelling and data structuring. In building such models, entity, activity, element and purpose forms the basic building blocks. The mechanisms and the

semantics terms are defined in the conceptual models to organize the information and set assumptions relating to the application being modelled. For instance, the conceptual model expresses terms such as the entities' properties and relationships when an application includes interrelated entities. The formal representation of knowledge in a particular domain is called Ontology. Typically, an ontology represent an hierarchical arrangement of domain concepts, the attributes of the concepts and the semantic relationships among the various concept of the domain. It involves the structural organization of domain knowledge in such a way that the both human and computers can read and understand.

Ontology as a philosophical study of being deals with concepts relating to being, the existence, the reality and their basic categories and relationships. Traditionally, it was listed as a part of metaphysics which is a major branch of philosophy. It generates answers to questions about what entities exists and how they can be grouped, how they can be related within an hierarchy and how they can be subdivided based on their similarities and differences. According to (Kepler,2006), ontologies aids human communication, facilitates communication between software systems and achieves interoperability . It provides the metadata for representing domain concepts with the vocabulary used in their annotation and transformation into semantic annotations. . It defines common vocabulary which can be used for information sharing in a particular domain. Machines are able to exchange semantics along with the syntax through the definition of common and shared concepts provided in the ontologies. Interoperation between Web applications from different views on a single area or from different areas is enabled through Ontology (Taye,2010). (Mihoubi,2000) states that " the goal of an ontology is to achieve a common and shared knowledge that can be transmitted between people and between application systems". (Dou,2005),(Kepler,2006), (Tidwell,2000) reported that on the Semantic Web and across organizations, ontologies play an important role in achieving interoperability because the aim is to capture domain knowledge and to generically create semantics explicitly in such a way that provides basis for agreement within a domain. Thus, ontologies have become a popular research topic in many communities.

Medical and Health care domain can be described as a domain with a very wide mixture of terminologies requiring comprehension and a great need for system integration. Doctors and medical practitioners have develop individualized special languages and lexicons for efficient communication and storage of general medical knowledge and information relating to patients. There is need for a secure and efficient communication of complex and detailed medical data (Ianace, 2015). The construction of a medical domain ontologies is a way by which this arduous and difficult task can be realized. An in-depth analysis of the concepts and structure of medical terms towards the development of an healthcare ontology promises a great support for the development of a system for integration of knowledge and data. The healthcare ontology will be able to proffer solution to the difficulty that automated medical systems have with multiple terms which represents same thing.

This systematical review of healthcare ontology seeks to find the existing methods, steps, techniques, strategies or initiatives being employed to establish ontology in the medical sector. Also to find out the ontological approach the researchers employed in achieving their research application focus as well as their recommendation considerations in terms of results obtained in respect of the ontological approach used.

MATERIALS AND METHODS

We reviewed the literature with the objective of answering the following study questions:

1. What are the existing methods, steps, techniques, strategies or initiatives being employed to establish ontology in the medical sector.

2. What is the research application focus of the paper and which ontological approach was employed.

3. What are the recommendation considerations in terms of results obtained in respect of the ontological approach employed.

The guideline that is employed for conducting the systematic review in this research work is that which was proposed by (Kitchenham,2007). Kitchenham states three major processes involved in conducting a systematic review: Planning the review, conducting the Review and reporting the review. During the planning, there is need to identify the need for the review, specify the research questions and develop the review protocol. This aspect of the need for the review has been shown in the introductory part of the review. The research questions were stated in the earlier part of this section . The Kitchenhan's approach in conducting a systematic review is a good and well accepted guideline for researchers in requirements engineering. It gives the potential for possible planning and execution of systematic review in software engineering. The method for this review work method was based on this research protocol explaining the strategy that was used in the literature search, studies selection, sources and selection and the reporting is done based on the format specified in the Kitchenham's approach.

DATA SOURCES AND SEARCH STRATEGY

The Google Scholar, Scopus and Web of science were searched for proceeding from conferences and journal papers between 2009 and 2018.. "Ontology and Health Care" was first used as the string term for the literature search. Keywords, abstracts and article's title were also

used during the literature search. "Health Ontology and Diagnosis System" search string was also used.

The sources of the literature search using the search string mentioned above is shown in table 1 for conference proceeding and table 2 for journal articles. In selecting the actual papers to be included, a manual review of eligible publication was carried out.

Table 1: Literature sources from conference proceedings

1. International Conference on Industrial, Engineering and Other Applications of Applied Intelligent Systems
2. Proceedings of The Workshop on New Trends of Computational Intelligence in Health Applications
3. International Conference on Biological Ontology
4. International Conference of the European Federation for Medical Informatics, Quality of Life through Quality of Information
5. The International Archives of Photogrammetric, Remote Sensing and Spatial Information Sciences
6. Proceedings of the 50th Computer Simulation Conference

Table 2: Literature sources from selected journals

1. Informatics for Health and Social Care
2. Doctoral dissertation, Master Dissertation from Institute Superior Técnico
3. Online journal of public health informatics
4. Annual Review of Biomedical Data Science
5. Journal of healthcare engineering
6. International Journal of Technology Management,Universitiesi Agder; University of Agder
7. Journal of biomedical informatics,Universitat Rovira i Virgili: Tarragona, Spain
8. International Journal of Computer Applications

9. Doctoral dissertation, City University London
10. Medical Informatics Europe

STUDY SELECTION

The search execution of the first search string was performs to get the first list of eligible publication for further evaluation. The verification of the articles was essential ensuring that their studies appropriately fits into providing answers for the research questions that were presented in this research work within the last 10 years. The following publications meet up with the defined criteria for eligible publications:

•   Abburu and Golla (2014) - Ontology-driven knowledge-based health-care system an emerging area - challenges and opportunities – Indian scenario.

•   Angelique (2014) - Ontology-Based Personalized System to Support Patients at Home.

•   Bertaud et al. (2011) - Ontology and medical diagnosis.

•   Cameron et al. (2015) - An Ontology of mHealth.

•   Dias (2012) - A Method for Improving Healthcare Management Using Enterprise Ontology.

- Dimitrieski et al. (2016) - A survey on Ontologies and Ontology Alignment Approaches in Healthcare.

- Duncan et al. (2015) - Building an Ontology for Identity Resolution in Healthcare and Public Health.

- Forbes et al. (2012) - Development of Patient-Practitioner Assistive Communications (PPAC) Ontology for Type 2 Diabetes Management.

- Haendel et al. (2018) - A Census of Disease Ontologies.

- Ismail et al. (2017) - A Granular Ontology Model for Maternal and Child Health Information System.

- Macris et al. (2009) - Using ontology-based knowledge networks for user training in managing healthcare processes.

- Pam (2014) - A Pilot Ontology for a Large, Diverse Set of National Health Service Healthcare Quality Indicators.

- Puri et al. (2011) - Multiple Ontologies in Healthcare Information Technology: Motivations and Recommendations for Ontology Mapping and Alignment.

- Rahimi et al. (2012) - Developing an Ontology for Data Quality in Chronic Disease Management.

- Ramadoss (2014) - Ontology Driven Model for an Engineered Agile Healthcare System.

- Riano et al. (2012) - An Ontology-based personalization of health-care knowledge to support clinical decisions for chronically ill patients.

- Romero (2009) - Ontology-Based Diagnosis and Personalization of Medical Knowledge.

- Traoré (2018) - Ontology for healthcare systems modeling and simulation.

- Vyas and Pal (2012) - E-Healthcare Decision Support System based on Ontology Learning: A Conceptual Model.

- White and Roudsari (2015) - Ontology for Healthcare Quality Indicators: Challenges for Semantic Interoperability.

All these articles were reviewed to extract necessary information in answer to the research question stated above.

DATA EXTRACTION AND SYNTHESIS

The extracted information from the studies includes the steps, methods, techniques, initiatives and strategies that is use in establishing ontology in the medical sector. The forms of information that were defined to carry out this review comprises of identification of studies, motivation, methods, the results obtained, as well as the strengths and the weaknesses. The approach used in the ontology design forms the basis for consideration in the extraction of methodology, so also the research focus, the employed techniques as well as their recommendation consideration. The result consideration is based on ontology approach employed and application focus research.

Abburu and Golla (2014) - Ontology-driven knowledge-based health-care system an emerging area - challenges and opportunities – Indian scenario.

These authors were motivated by the most important source of knowledge, which is the ontology that contains every significant domain concepts such as, diseases, environments, locations including their domain sensitive inter-relationships among the concepts. Their recent studies showed that the record of Ontology has so much had influence in the efforts involved in the aspect of decision making in respect of public healthcare systems. The development of a semantic knowledge-base for public healthcare system formed their main focus. The approach and methodologies they used in bringing out a novel conceptual theme was described. In their research methods and approach, the ideal of health mapping methods was adopted. Interoperability issues and reusability of health applications were based on mapping of the data attributes together with ontological concepts. This was used in generating semantic integrated data which drives an inference engine for user-interfaced semantic queries. They proposed a platform that was in correlation with the real-time mechanisms prevailing within the semantic knowledge-base and establishing their inter-relationships.

The extracted disease data were evaluated from structured and semantic heterogeneous health record used in hospitals, clinics and medical centres in Krishnagiri district, Tamilnadu, India.

They developed a centralised semantic knowledge base for healthcare system in India through extracted data in Resource Description Framework-RDF triple format and implemented it using Java, Jena API, oracle semantic store and Java script.

The results showed an onto graph notation of linked ontologies as well as RDF representation of sample Electric Health Record-EHR data which made the implementation encouraging.

Angelique (2014) - Ontology-Based Personalized System to Support Patients at Home.

The author was motivated by the challenges patients with chronic diseases such as obesity, respiratory diseases, cardiovascular disease, cancer and diabetes experience, patients not being able to acquire regular supervision at home. She identified Information and Communication Technology- ICT as a major solution to improving the quality of life for such patients which can be achieved through the implementation of different chronic diseases remote supervision

applications. She stated that since the number of chronic patients was on the increase, the need for large patient data management is inevitable. As such, there is need to improve the existing technology in order to make shared services available. She identified that the current web has to be transformed into ontology based technology which would help in the easy collection, storage and sharing of a large amount of data. She intended using Ontology-Based Personalized System to support Patients with chronic diseases to be supervised at their home. The Ontology was built using Protégé-owl editor tool. She presented a knowledge representation model based on Protégé for linking concepts and data for diabetes diseases. She used Onto Graph for displaying the content of the model showing all the relationship between the various instances. Setting up of rules and information retrieval from the ontology repository was done using SPARQL. The system was then recommended to be used to help in improving the self-management capability of diabetic home patient.

Bertaud-Gounot et al. (2011) - Ontology and Health diagnosis.

The authors were motivated by the need to classify patient's characteristics under a particular disease. The research was focused on the evaluation of the extent ontology can act in supporting disease classification services. In their work, an ontological representation which considers the classification of specific patient conditions under a specific disease class based on diagnostic criteria. Protégé 4 and OWL 2 were used to model the ontology, allowing data properties to be created and qualified data restrictions formalizing the relationships between data values and the classes. The diagnostic classification, which group each patient under a particular disease was done using the record of a set of thirty patient that had back pain with a time range of 1 month to 3 years. The HermiT 1.2.2 reasoner was used to create and classified each record class. Their research work demonstrated the possibility of representing operational definitions of diseases using OWL as well as the classifying of real patient cases.

Cameron *et al*. (2015) - Ontology o f mHealth

The authors presented ontology of mobile Health which explained the combination of its complexity. They described how the ontology could be used to define the domain of mHealth, and how it could be extended, reduced, refined, to adapt to the changes in technology and environment for healthcare. Structured natural English sentences and phrases was used by the ontology to explain the components and fragments which the mHealth was made of. They outlined the state-of-the-research and the state-of-the-practice in mHealth, how these can be mapped using ontology. The gaps in research with the gaps between research and practice were itemized, and the discovered strategy that could bridge the gaps were expressed

Dias (2012) – A Method for Improving Healthcare Management Using Enterprise Ontology

The author identified the inefficiency and unsustainability of the healthcare systems which has contributed to the high failure rate of healthcare systems'. The need to reduce this motivated this research work.

The author proposed a method to study organization and its processes referred to as Enterprise Ontology, for finding non value-added transactions which is to be modelled and redesigned for improving the healthcare management. The Design Science Research Methodology- DSRM (artifact method) was used to conduct the research focusing on Lean which was grounded in the PDCA Operating Framework for removal of time wastage to improved flow time. DSRM was applied to healthcare units that included a hospital ED, a Pharmacy and a PHC, to demonstrate effective and efficient application of the proposed method, Enterprise Ontology in solving the research problems irrespective of whomsoever applies it. The evaluation of the DSRM artifact was verified which showed the validity of the artifact in that it improved the healthcare management, compared with the approaches of the current state-of-the-art. Hence, the results showed that the artifact was effective as well as efficient which was able to address the research problem (to improve healthcare operational process).

Dimitrieski *et al.* (2016) - A survey on Ontologies and Ontology Alignment Approaches in Healthcare

The authors were motivated by the problem created from the coexistence of multiple representations in healthcare development as there were large number of ontologies, vocabularies and taxonomies which has made it difficult to achieve a single but general ontology. They thought a healthcare was to assist medical personnel in their activities. Their focus was on providing an overview of healthcare ontologies and an healthcare ontologies' critical review that existed with the various approaches to integrating healthcare. In line with the Yosemite initiative, they proposed the use OWL/RDF as a solution for greatly reducing the order and complexity in the existing confusing healthcare ontologies. They felt the approaches of Yosemite initiative would simplify the complicated Ontology alignment field. They showed with the review that no all-inclusive overall solution has surfaced which can allow a semi-automatic or automatic healthcare integration information systems.

Duncan *et al*. (2015) - Building an Ontology for Identity Resolution in Healthcare and Public Health

The authors' motivation was from complications of record linkage as a result of issues of structure and meaning diversity. It was stated that the correct matching of patient-specific records depended on integrating information from birth certificate registries, clinical data warehouses, electronic health records, and other systems for public health information, i.e. the issues of semantic and syntactic diversity. Their focus was either on investigating existing ontologies or developing and validating a new ontology from clinical and public health information systems that links birth and early- childhood records. Uschold and Gruninger

method was used to develop the ontology. They interviewed experts from related hospitals and public health fields and developed process models that showed that there were similarities in administrative events for a child's after birth event. They looked for existing ontologies that are relevant, and with simulated identity information that was similar to scenarios identified in the process models validates the content of their ontology. The ontology was represented using the the Protégé OWL Editor and Web Ontology Language (OWL). They use the SEM-CEM ontology to create a simulated birth-certificate knowledgebase in Protégé. The results showed that the use of an ontology can overcome issues of semantic and syntactic diversity to facilitate record linkage. However, the research was limited such that the observed and modelled activities were in some health filed which may not be in accordance to other settings.

Forbes *et al*. (2012) - Development of Patient-Practitioner Assistive Communications (PPAC) Ontology for Type 2 Diabetes Management.

The authors were motivated by the slow response of primary care settings communication, a major area of healthcare that needs to employ new technology that would speed up communication between the healthcare practitioners and their patients. The research was focused on primary care and face-to-face Patient- Practitioner Interview Encounters (PPIE) of the chronic disease type 2 diabetes mellitus in indigenous people. They developed a Type-2 Diabetes Management Patient-Practitioner Assistive Communications (T2DMPPAC), an Ontology that links medical information with different languages for easy communication between healthcare practitioner from a different cultural group with the patients from a minority group. However, their research work wasn't complete as many medical words and phrases used within the indigenous community were lacking in their indigenous English ontology.

Haendel *et al.* (2018) - A Census of Disease Ontologies

 They stated that ICD, a disease classification maintained by the World Health Organization (WHO) was used by over 100 countries and translated into 43 languages. Hence, the struggle by humans to classify diseases based on phenotypes and available treatments was a much concern for the authors. However, they examined the rise of disease and phenotype ontologies and the different ways of their representation and application in biomedicine.

SNOMED-CT standard terminologies was used to collect the concepts based on the disease.

Ismail   *et al*.(2017) - A Granular Ontology Model for Maternal and Child Health Information System.

The research work was motivated by the aim to decrease child mortality by two-third and maternal mortality by three-quarters, respectively, according to United Millennium Development Goals (MDGs 4 and 5). To achieve Maternal and Child Health (MCH) targets in countries, there has to be investment in infrastructure, improvement in service delivery and also, availability of reliable health data. Reliable data have to be available to avoid statistics from being on estimates.

Hence, the aim of the research work was to design and develop a granular data model making use of existing standards to uphold maternal and child health data for effective healthcare data exchange. The authors used knowledge engineering approach, Meth-ontology, to design the proposed data model. A web-based application was implemented to determine how effective the proposed granular data model was. The system (MCHR) testing was carried out with five healthcare providers that involved 30 women who were pregnant or had a baby within last 6 months and they provided a sincere opinion regarding how effective the system was. The healthcare providers registered patients on the system and added their personal data and clinical history. The record was viewed by the patients which involves the checking of their pre-pregnancy and current BMI. The result, evaluated on the basis of user's opinion showed that most of the women understood all the relevant functions of the system, found the system to be effective in improving record keeping techniques, acknowledged the system features to be practical and useful in helping them track health status, and a lot of the doctors and women agreed to use the system because it was easy to use compared to traditional record keeping , thereby contributing to better and efficient healthcare delivery system. However, a major challenge encountered was lack of education and awareness of the system.

Macris *et al.* (2009) - Using ontology-based knowledge networks for user training in managing healthcare processes.

They presented an ontology-based knowledge network approach to construct user training scenarios on the concepts of healthcare process model in which the objects used and knowledge built were fully reusable. Their motivation was from their involvement in a project concerned with the design and implementation of a process-oriented healthcare system architecture that was across a health district. Their focus was to enable users get familiar with and actively participate in healthcare process modelling activities. They used CULTOS tools based on a reusable knowledge to build a sample training scenario in the healthcare domain. However, the approach was intended to be evaluated extensively by making use of more detailed implementation tools and real life healthcare processes scenarios.

White *et al.* (2014) - A Pilot Ontology for a Large, Diverse Set of National Health Service Healthcare Quality Indicators.

The project work aimed at reducing repeated effort in finding data for NHS healthcare quality indicators, and to know areas for future computer-interpretable quality indicator development.

The author was motivated by the need to improve Healthcare Quality Monitoring. Meth-ontology which involved (specification, knowledge acquisition, conceptualisation, integration, formalisation, implementation, evaluation, documentation, and maintenance) was used to develop the ontology. He identified relationships between indicators, and also an initial set of inclusion and exclusion criteria. He used Protégé 3.4.1 as the platform to develop a pilot ontology and also, 222 of quality indicators to justify the development of a separate ontology.

The result showed that information can be gathered from the ontology through queries which made it useful to clinical auditing communities, quality indicator developers, organisers of quality indicator sets and providers of access to quality indicator sets so as to reduce effort involved in healthcare quality monitoring. However, the project work was limited by unknown changes in the indicators, lack of previous experience in ontology development, lack of medical knowledge, lack of previous experience in clinical coding and poor quality metadata about the indicators.

Puri *et al.* (2011) - Multiple Ontologies in Healthcare Information Technology: Motivations and Recommendations for Ontology Mapping and Alignment.

The authors were motivated by the need for proper data analysis and integration which would reduce health care costs as well as improve the quality of care. They proposed the use of several ontologies that make good integration and analysis of data because a single ontology was not enough to meet the need of quality health care. Ontologies are meant to be integrated together for support of data integration and analysis. The project work focused on challenges that occur when integrating multiple ontologies.

They stated that approaches such as UMLs, OpenGALEN, and 3M's Health care data dictionary have been tried to integrate multiple ontologies. Those approaches only provide mappings between different biomedical ontologies. However, they stated BLOOMS has been applied successfully to align disparate ontologies in the Linked Open Data Cloud and therefore recommended BLOOMS to be considered as an engine to align disparate biomedical ontologies.

Rahimi *et al*. (2012) - Developing an Ontology for Data Quality in Chronic Disease Management.

The use of Clinical Information Systems (CIS) for chronic disease management (CDM) has been increasing. Improvement in data quality (DQ) is capable of improving the quality of decisions, evidence-based care and patient outcomes.

The authors described the methodology and progress of the development of an ontology to assess DQ in diabetes. They aimed at developing an existing framework and methodology to guide the development and validation of DQ ontology in CDM.

They conducted a review that addressed the functions of ontologies in the assessment, collation and management of DQ in health care. The result identified the useful ontologies tools which include Protégé, SNOMED CT and UMLS. METHONTOLOGY was identified as the most mature of ontology methodologies. However, the implementation and evaluation stages were not completed.

Ramadoss (2014) - Ontology Driven Model for an Engineered Agile Healthcare System

The author was motivated by the need for an effective way to manage the complexity of healthcare system in order to produce quality outcome. However, he presented a health care specific framework and methodology to translate data into desired quality outcome in order to address the need of hospitals to meet the challenge of lack of a systemic view of patient and patient care. He proposed a patient-care level process based ontology and created a bridge that applied systems engineering principles to allow observation and control of the system.

Healthcare Ontology Based Systems Engineering Model (HOB-SEM) was applied to persistent health care issues for implementation. The methodology was shown with respect to disease management. However, an extension to personalized medicine was not developed.

Riano *et al*. (2012) - An Ontology-based personalization of health-care knowledge to support clinical decisions for chronically ill patients.

The need for chronically ill patients to be assisted by multiple medical professionals motivated the authors for this project work. They introduced an ontology to take care of chronically ill patients and implemented two personalization processes and a decision support tool.

They developed a knowledge based; case profile health care ontology and that organized the terms that described chronically ill patients. The case profile ontology is an OWL-DL compliant ontology which was developed in the K4CARE project so as to give a representation of all health care concepts that are related to chronically ill patients.

23 out of 400 chronically ill patients were selected to perform a ground test. At the end of the testing, the following results were gotten, having 1(low) and 7(high): mean overall score of the evaluation and perceived ease of use were 5.8, perceived usefulness was 5.9, attitude toward using was 6.0, need of such systems in health care was 6.3 while awareness of some similar system was 1.9. The ontology was intended to extend SDA Lab tool with a process to supervise the action block of the unified intervention plan.

Romero (2009) - Ontology-Based Diagnosis and Personalization of Health Knowledge.

The author focused on solving diagnosis as a medical problem. The project was about developing a knowledge-based application to guide medical practitioners in the diagnostic process. The Case Profile Ontology on the medical domain was used. The project was integrated in the European Project K4CARE which was aimed to design, implement and validate a new ICT knowledge-based Homecare Model.A conclusion was reached that the validation tool was capable of detecting the diseases that should appear on the diagnosis. Notwithstanding, one of the problems encountered was that to check the patient's results, it is necessary to be a physician or to have medical knowledge.

Traoré (2018) – ontology for healthcare systems modelling and simulation.

The project proposed a System Entity Structure (SES) Ontology for Healthcare Systems' Modelling and Simulation (O4HCs). The author was motivated by a high degree of complexity often confronted with the challenge of formulating a simulation model that captures this complexity in a systematic and manageable manner. A clearly stated ontology that supports simulation methodology for addressing healthcare systems analysis was presented. However, a lot has to be done for the ontology to be widely accepted.

Vyas and Pal (2012) – E-healthcare Decision Support System Based On Ontology Learning: A Conceptual Model.

The authors were motivated by the lack of effective tools for data analysis. They were focused on developing an Electronic health care system to improve the health care services.

They stated that e-health care system would enable patients to receive better and faster health care from their providers anytime and anywhere. The system would help to handle track record of patients. Ontology design was considered to be a creative approach for the proposed e-health solution model which would be helpful for both doctors as well as patient to provide high quality service in low cost. However, the project work was not fully implemented but OWL in combination with SWRL were suggested to be used for handling reasoning in complex medical systems.

White and Roudsari (2015) - Ontology for Healthcare Quality Indicators: Challenges for Semantic Interoperability.

The authors were motivated by the need to reduce repeated effort in finding data indicator components. They developed a pilot ontology that emphasises relationships between layers of inclusion and exclusion criteria for a large and different set of healthcare quality indicators. The ontology has the potential to reduce duplication of effort to find data for indicator components and to link to EHRs through clinical codes. Methontology was chosen to develop the pilot ontology for a set of healthcare quality indicators. To create the ontology, Protégé was selected as the development platform. They evaluated the ontology for consistency, conciseness, completeness, expandability, and sensitivity. However, the ontology showed some weakness in the area of conciseness which makes the Ontology worth further development.

The main contributions, in terms of approaches to developing an ontology based model in health care are shown in Table 3 below:

A u t h o r	A p p r o a c h	M a i n c o n t r i b u t i o n
Abburu and Golla (2014)	Java Jena API ,Oracle semantic store and Javascript	• Development of a centralized semantic knowledge base for

		healthcare
Angelique (2014)	Protégé-owl editor tool, SPARQL	• Improved diabetic home patient self-management capability. • Modeling of Protégé-based knowledge representation for linking concepts and data for diabetes diseases
Bertaud et al. (2011)	Protégé 4 and OWL 2	• Diagnostic classification of real patient cases
Cameron et al. (2015)	Mobile +Ontology	• Mobile based health care ontology
Dias (2012)	DSRM PDCA	• Reduction of the high failure rate of healthcare systems • Removal of waste to improve flow time • Improving healthcare operational process
Dimitrieski et al. (2016)	OWL,RDF	• Solution to reduce complexity in existing healthcare ontolgies • Approaches to healthcare integration • Critical overview of healthcare ontology
Duncan et al. (2015)	OWL,Protégé OWL Editor	• Development of a new ontology in public health system • Validation of the content of the ontology

Forbes et al. (2012)	Ontology	• Improving communication between the patient and healthcare provider • Development of a type2 diabetes management patient-practioner assistive communication • Classification of diseases based on phenotype
Haendel et al. (2018)	SNOMED-CT	• Reduction of child and maternal mortality
Ismail et al. (2017)	Ontology	• Improvement in service delivery, availability of reliable health data • Development of a granular data model • Enablement of users to actively participate in healthcare process modeling activities
Macris et al. (2009)	Ontology-based knowledge network	• Reduction of repeated effort in finding data
Pam (2014)	Protégé 3.4.1	• Improving healthcare quality monitoring • Development of a pilot ontology • Use of several ontology for proper data analysis and integration
Puri et al. (2011)	UMLs,OpenGALEN and 3M's	• Motivations and recommendation for ontology mapping and alignment • Development of an ontology to access DQ in diabetes • Framework development to guide the development and validation of

		DQ ontology in CDM
Rahimi et al. (2012)	Protégé, SNOMED CT and UMLs	• Framework representation to translate data into desired quality outcome • Application of HOB-SEM to persistent health care issues for implementation
Ramadoss (2014)	Ontology	• Development of a knowledge based case profile health care ontology
Riano et al. (2012)	OWL-DL ontologyK4CARE *Ontology*	• Introduction of an ontology for chronically ill patients
Romero(2009)	K4CARE	• Designing, implementation and validation of a new ICT knowledge-based homecare model
Traoré (2018)	OWL ,SWRL	▪ Modeling and simulation of a system entity structure ontology for healthcare ▪ Development of a knowledge based, case profile health care ontology.
Vyas and Pal (2012)	Ontology	• Development of an Electronic Health care system to improve health care services.

White and Roudsari(2015)	*Ontology*	• Development of a pilot ontology for reduction of repeated effort in finding data. • Evaluation of the ontology for consistency, conciseness, completeness, expandability and sensitivity.

Table 3: Summary of contributions and approaches considered

RESULT AND DISCUSSION

Out of the Twenty (20) project works considered, Seven (7) of the initiatives of the research works considered were of Methodology, Two (2) were technique based, Three (3) were Framework based, Two (2) were Process based while Six (6) were extensions of those in existence.

Table 3 above showed that the approaches considered were ontology based in terms of the use of Protégé-owl editor tool, SPARQL, Protégé 4, OWL 2, OWL, RDF, SNOMED CT. The main contributions include but not limited to; Modelling of Protégé-based knowledge representation for linking concepts and data for diabetes diseases, Mobile based health care ontology, classification of diseases based on phenotypes, improvement in service delivery and availability of reliable health data.

The result of the review is shown in Table 4 below. It gives summary of quantity of studies per initiative discovered. It showed the statistics of features which attempt to improve healthcare operational processes. These features are capable of being used as basis for techniques/ frameworks/ process/ methodology, or as extensions to those that already exist.

Types of Initiative	Number of studies	
Methodology	7	4.1,4.7,4.10,4.12,4.14,4.18,4.20,4.2,4.11
Techniques	2	4.5,4.15,4.19

Framework	3	4.16,4.17
Process	2	4.3,4.4,4.6,4.8,4.9,4.13
Others	6	
Total	20	

Table 4: summary of quantity of studies per initiative

CONCLUSION

This review work gives a summary of existing literature on the concept of ontology in health care. It makes contribution by making available to researchers in the field detailed information on the existing approaches, the contribution to improve quality of health services and limitations. It also showed the motivations of various researchers, their contributions to improve health care through the use of ontology and the limitations in their research works. Also, it was shown that various researchers in this field deployed different approaches to improve health care through Ontology. Some approaches were Methodology based, Techniques based, Process based, Framework based while others were extension of those that existed. This heath care ontology review which was carried out showed the need of Ontology based models to improve health service delivery for both the users (patients) and the care providers. This research work could be employed in guiding researchers in the area of health ontology on gaps and areas that could be looked into or improved upon in the field. This will further contribute to the contribution of the research area.

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