

HNS Ontology Using Faceted Approach†

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Abstract: The purpose of this research is to develop an ontology with subsequent testing and evaluation, for identifying utility and value. The domain that has been chosen is human nervous system (HNS) disorders. It is hypothesized here that an ontology-based patient records management system is more effective in meeting and addressing complex information needs of health-care personnel. Therefore, this study has been based on the premise that developing an ontology and using it as a component of the search interface in hospital records management systems will lead to more efficient and effective management of health-care. It is proposed here to develop an ontology of the domain of HNS disorders using a standard vocabulary such as *MeSH* or *SNOMED CT*. The principal classes of an ontology include facet analysis for arranging concepts based on their common characteristics to build mutually exclusive classes. We combine faceted theory with description logic, which helps us to better query and retrieve data by implementing an ontological model. Protégé 5.2.0 was used as ontology editor. The use of ontologies for domain modelling will be of acute help to doctors for searching patient records.

In this paper we show how the faceted approach helps us to build a flexible model and retrieve better information. We use the medical domain as a case study to show examples and implementation.

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† To access our ontology, download the owl file and upload into the WebProtégé tool. The following links will help you to download and access our ontology:

- HumanNervousSystem.owl raw file can be download from GoogleDrive link:
<https://drive.google.com/file/d/1Aw7LPafkCYSaorxjPJMvC8Nr2es9iPVk/view>
- Link to access HumanNervousSystem.owl file in the WebProtégé:
<https://webprotege.stanford.edu/#projects/a5ba0b79-4141-4612-8252-4714a538cd6b/edit/Classes>

1.0 Introduction

Ontology has been defined as the conceptualization of a domain. The term is somewhat ambiguous, insofar as it has been employed to refer both to an artifact and to a set of philosophical principles. Indeed, the term ontology has been used in a number of different senses in different scientific fields. Nonetheless, it is in its association with computational approaches that it has acquired importance and prominence in recent years. This is because when the term

became popular in the 1990s, ontology was used as a new catchword for knowledge representation artifacts in expert systems. It is used in this field to refer to a detailed schema of a "slice of reality" based on known facts about that reality (domain). In the fields of information retrieval, content management and knowledge management, ontologies are increasingly being seen as tools for knowledge representation to facilitate, support and enhance the quality of resource discovery and information retrieval. Ontologies play an important role in the semantic web, and the number

of ontologies in a wide range of domains has been developed, which is a clear indication of the growing recognition of the importance of ontologies (Naskar and Dutta 2016).

An area that has seen quite a few research papers in the application of ontology is the domain of health care and delivery. Khoo et al. (2011) have demonstrated that an ontology can support evidence-based medical practice and alert doctors to the range and quality of clinical data available to make informed treatment decisions. Shepherd and Sampalli (2012) have shown the use of ontologies as boundary objects that could help enhance the quality of health-care and delivery. Lee et al. (2004) have worked on automatic methods to identify treatment relations in medical ontology. Khoo and Na (2009) developed an ontology to represent the knowledge-base for a clinical decision support system for wound management. There is a considerable degree of interest among LIS professionals in the use of ontologies for domain modelling as evident from the papers on the subject (Prieto-Díaz 2003). The patient record management systems in use in many hospitals also suffer from limitations in terms of their ability to support complex searches; for example, consider a request for records of patients in a certain age group with certain specified symptoms and ailment, treated with a particular drug having some after effects. Such a complex query may be difficult to meet using the systems that are used in most hospitals. This is particularly evident in the records of patients that are maintained in hospitals. A major factor is that data input to patient records are made by health-care personnel of different types and levels, e.g., physicians, pathologists, surgeons, nurses, physiotherapists, etc. This leads to a considerable degree of inconsistency in the vocabulary/terminology used in describing symptoms, diseases, etc. Motivated by these contrasting observations on effectiveness of using ontologies in different domains, we restructure ontology for relevant purposes and attempt to improve delivery of quality health-care service. The purpose of this paper is to develop an ontology related to human nervous system (HNS) disorders—for evaluating its utility and value. We perform complex queries to address relevant information needs of health-care personnel. Using an ontology as a component of the search interface in hospital records management systems will lead to more efficient and effective management of health-care.

It is proposed here to develop an ontology of the domain of HNS disorders using a standard vocabulary such as *Medical Subject Heading (MeSH)* or Systematized Nomenclature of Medicine - Clinical Terms (SNOMED-CT). The principal classes of the ontology will include: HNS, diseases/disorders, diagnosis, treatments/therapy, symptoms, side effects, etc. In this paper, we have demonstrated an ontology-based modelling of HNS disorders using Ranganathan's faceted approach (1937), a well-known principle

in library and information science, which is generally used for classifying different domains. Faceted classification is “the sorting of terms in a given field of knowledge into homogeneous, mutually exclusive facets, each derived from the parent universe by a single characteristic of division” (Vickery 1968), described in Ranganathan (1937) and implemented in Ranganathan (1989).

The rest of this paper is organized as follows. Section 2 reviews the related work. Section 3 describes the evaluation of the faceted theory. Section 4 explains different requirements and methodologies of building ontologies. Section 5 shows the method of verification by implementation. Section 6 explains the process of evaluation by SPARQL queries. The final section concludes and explains the direction of our future work.

2.0 Literature review

There are a number of studies regarding the modelling of the medical domain that propose various opinions and methodologies for its detection.

2.1 Medical ontology

Some well-known researchers built different ontology models related to a medical domain (brain tumor, nervous system) by proposing their opinions and methodologies. Khoo et al. (2000) developed a method to extract knowledge and to identify the information that is explicitly expressed in medical abstracts in the Medline database. They used Conexors FDG parser to construct a syntactic parse tree for each target sentence and four medical domain areas related to heart disease, AIDS, depression and schizophrenia. Lee et al. (2003) developed an automatic method from existing ontologies to identify semantic relations between the concepts in a medical domain by using the UMLS (Unified Medical Language System) semantic net. Murugavalli and Rajamani (2006) carried out a high speed parallel Fuzzy C Means (FCM) algorithm for brain tumour segmentation for the clustering of both the sequential FCM and parallel FCM. The following year, Murugavalli and Rajamani (2007) came up with an improved implementation of a brain tumor detection technique using segmentation based on the Neuro-Fuzzy technique. Khoo et al. (2011) have shown that the basic idea is that a training set of documents is used to build the ontology. Then a test set is used to evaluate whether the ontology covers most of the relevant concepts and relations in the domain. They applied the UMLS semantic network, *MeSH*, and the National Cancer Institute (NCI) thesaurus as the base medical ontology, enriched with relations to link potential medical treatments with diseases. Shepherd and Sampalli (2012) built an ontology based on SNOMED-CT as a boundary

object to bridge the semantic interoperability gap between members of multidisciplinary health-care teams caring for patients with chronic diseases. In recent years, different approaches proposed for learning ontologies in the medical domain. Likewise, Rios-Alvarado et al. (2015) proposed a new ontology learning approach that discovers hierarchical relations and axiom extraction over the medical domain. One interesting study by Alkhamash et al. (2016) designed an ontology associated with water quality and kidney diseases to assist physicians in predicting certain diseases such as the existence of stones, gravels and cancer. Puri et al. (2011) suggested an ontology-based approach to integrate heterogeneous healthcare data for building a recommendation system.

Recently human nervous system ontology has gained more popularity. Hamilton et al. (2012) proposed an informatics infrastructure to describe neurons through a standard terminology. They also discussed current national and international efforts to address the complexity of neuronal types within the Neuroscience Information Framework (NIF) and the International Neuroinformatics Coordinating Facility (INCF) Neuron Registry initiative. Similarly, Imam et al. (2012) developed a knowledge model called Neuroscience Information Framework Standardized Ontologies (NIFSTD) which provides an extensive collection of standard neuroscience concepts along with the synonyms and relationships. Another interesting study was done by Köhler et al. (2016), defining a characteristic of the nervous system with principles of ontology. They followed nine steps (including thresholding, watershed segmentation, morphological operation) for detecting disease matching them with their existing database containing images of neurologic diseases. In a recent study done by Polavaram and Ascoli (2017), where they established an ontology-based search engine of interconnected hierarchies focusing on the main dimensions of animal species, anatomical regions, and cell types. They mapped each metadata term into the formal ontology that explicitly resolves all ambiguities caused by synonymy and homonymy.

2.2 Faceted approach

There is a considerable degree of interest among library and information science (LIS) professionals in the use of ontologies for domain modelling as evident from the number of papers on the subject. Several studies have been carried out regarding the modeling of ontologies and proposed faceted approaches for classifying, organizing and searching web documents. Earlier, Ellis and Vasconcelos (2000) used faceted classification in subject directories and search engines and Yee et al. (2003) for retrieval of images from a large database collection. Broughton (2006) estimated the impact of faceted classification and used a fac-

eted approach for the purpose of development of various information retrieval tools. She found that the faceted approach as a standard theory can function as a tool for browsing, for navigation and for retrieval. Correspondingly, work by Agostini et al. (2011) represented a formal framework to refine the original query for search and retrieval purposes by using general principles of faceted classification. They used ALC (attributive language complex concept negation) description logic to implement the facet engine as the main component of this method. ALC is a core attributive language (AL)-based description logic which complements (ALC); unlike AL, the complement of any concept is allowed, not just the complement of atomic concepts. From the permissible constructors' point of view, ALC would be equivalent to AL Concept Union and Full Existential qualification (ALUE), although the latter name is not used. ALC concept expressions can include concept names, concept intersection, concept union, complement, existential and universal quantifiers, and individual names (Donini et al. 1997; Baader et al. 2003).

Prieto-Díaz (2003) proposed a faceted classification method to build an ontology for identifying and categorizing concepts. Similarly, by using an analytico-synthetic approach, Ghosh and Panigrahi (2015) developed an ontology in the library and information science domain to prove the relevance and importance of Ranganathan's philosophy. To overcome semantic interoperability issues in a knowledge base system and to exploit the benefits offered by the state of the art technologies Hasan et al. (2015) developed an ontology named Earthquake Engineering Research Projects and Experiments (EERPE) using a faceted approach. Another study carried out by Das and Roy (2016), created a faceted based ontological framework on the brain tumor domain to retrieve and facilitate semantic query answering. Other notable work on the semantic web domain was influenced by faceted classification theory. For example, for the purpose of representing multiple classification criteria, authors Rodriguez-Castro et al. (2010) examined a simplified procedure to develop a faceted classification scheme (FCS) for domain specific concepts.

3.0 Evolution of faceted theory

According to Ranganathan's faceted classification (1989), knowledge can be divided into five fundamental categories: "personality" (P), "matter" (M), "energy" (E), "space" (S) and "time" (I)—well known as PMEST. The notion of a refined faceted theory proposed by Bhattacharyya (1981), consists four categories: "discipline" (or domain) (D), "entity" (E), "property" (P) and "action" (A), plus another special category called "modifier" (m); this is known by the acronym DEPA. DERA, which stands for "domain," "entity," "relation" and "attribute," is a faceted

knowledge organization framework. It makes a provision for the organization of knowledge into facets by defining them as per their domains (Giunchiglia et al. 2014). In DERA, domain consists of three elements, namely “entity” (E), “relation” (R) and “attribute” (A), i.e., $D = \langle E, R, A \rangle$. We would like to describe the HNS ontology from the DERA perspective. In this ontology, the nervous system is a “domain” (D), which contains a class, relation between classes or objects and attribute or characteristic for refining class or entity. Entity is (Giunchiglia et al., 2014, #51), “an elementary component that consists of classes (categories) and their instances, having either perceptual correlates or only conceptual existence in a domain in context.” This entity definition is slightly different from Bhattacharyya’s definition of entity (Bhattacharyya 1975) although the main idea derives from it.

3.1 Advantages

The main advantage of the faceted approach is to make logical explicit relationships among the concepts or group of concepts and ignore the limitation of traditional hierarchies. Some more advantages of the faceted approach are given below:

- Hospitable: the classes are easily extensible. The new classes or schema can accommodate without any difficulties.
- Flexible: the classes are more flexible on the basis of creating structure, sharing with others to facilitate searching and navigating.
- Reusable: a facet-based ontology allows many different aspects and approaches to the items, which may be reusable for other related domains.
- Homogeneity: a faceted approach represents a group of concepts based on their homogeneous characteristic(s), which also solve the problem of polyhierarchy.
- Compact and Completeness: a faceted approach holds complete structure of classes and subclasses and requires compact space with comparison to other hierarchical knowledge organization systems.

3.2 Adaptation

Health-care information systems (HIS) are somewhat fragmented in terms of design and operation, as a result of successive projects that are not well coordinated or harmonized with the existing public health systems. A “bottom-up” approach for designing and implementing systems may also contribute to fragmentation within a system.

Enterprise architecture (EA) is a common approach to develop a system that is more coordinated and integrated at a system level. EA has been described (Cameron and

Malik 2013, 1) as “a well-defined practice for conducting enterprise analysis, design, planning and implementing by using a holistic approach at all times for the successful development and execution of the strategy.” EA offers methodology and reusable architecture to systematically assist large-scale systems and helps to create a set of health architecture components that can be reused globally. EA could be a possible approach to design and develop health information systems for global health-care. However, some limitations that appeared on designing tool and technique for the HIS application include:

- lack of standardization, including the use of standards for data storage and interoperability;
- minimal interoperability between individual applications developed for a single solution;
- limited reuse of existing applications that are often engineered around a single application use case;
- lack of data integration as a result of different conceptual frameworks and lack of use of standards;
- poor data quality, often resulting from the lack of effective data use locally as well as poor data entry tool and training.

EA provides a methodology and reusable architectural assets that can assist in the development of complex, large-scale systems systematically and holistically, and can potentially create reusable architecture components for global health projects.

4.0 Methodology

In the past decade, ontologies have been used as a core in most knowledge-based applications (Kharbat and El-Ghalyini 2008). In the literature, several definitions of ontology are available. A definition is given by Benjamin et al. in the IDEF5 project (1994, 2):

An ontology is a domain vocabulary together with a set of precise definitions, or axioms, that constrain the meaning of the terms in that vocabulary sufficiently to enable consistent interpretation of statements that use that vocabulary.

Among other available definitions, probably the most relevant definition of ontology was proposed by Guarino (1998, 6): “a set of logical axioms designed to account for the intended meaning of a vocabulary.” In this definition, Guarino emphasized the role of logic as a way of representing an ontology. We believe that ontology has an important role to play in the general task of managing diverse information. Most of the work done in this domain is mainly focused on the design of an ontology for the infor-

mation system. In contrast, we focus on designing the ontology and also map it with upper-level ontology. Therefore, the work described here was motivated by the following research questions:

1. How does one design an adaptive model that answers various queries for the health-care system?
2. How does one align the model with any upper-level ontology?

Many diverse situations related to hospital, patient, doctor and event will make it challenging to come up with a full proof, simplified, and generalized query that will tackle every intricate situation. However, to minimize the challenge, we formulate our own steps to design the human nervous system (HNS) ontology, which is motivated by the work done by Gruninger et al. (1995). Our major focus was on the generation of axioms using description logic (DL) rather than using first order logic (FOL). DL possesses more advantages over FOL as it ensures more expressiveness of the model. Figure 1 shows all the steps that we followed to develop the HNS ontology. The steps are briefly enumerated below:

4.1 Steps in model generation

4.1.1 Domain analysis

In this process, we analyzed all components associated with the domain discourse (Guarino et al., 2009). Another task is to finalize the reference context in which we wanted to build the application. For example, we can build an application for the patient, doctor or hospital within the health-care domain. A feasibility study for the final application also needs to be undertaken in this step.

4.1.2 Identification of the terminology

We adopted a set of words for building an ontology. Words, in this context, are considered to be terms that represent particular concepts in a given natural language. For our work, technical terms have been collected from various literature published by different brain tumour associations and societies. As main sources of natural language terminology, we have selected a standard vocabulary such

as *Medical Subject Heading (MeSH)* and *Systematized Nomenclature of Medicine Clinical Terms (SNOMED CT) 2017 International edition*. Some of the terms have also been taken from a classification by The American Association of Neurological Surgeons.

4.1.3 Arrangement and alignment

The terminology collected during the previous step was analyzed for categorization and arrangement of terms according to their similarity and differences. We also analyzed which terms represent classes, properties and values. Here we considered only qualitative values. Qualitative values usually reflect properties values, which usually express concepts for the value rather than a number. For example, if we use “male” or “female” as values for the property “gender,” then the terms express a qualitative value. Qualitative values are usually useful when codifying disease names, treatment names or particular medical procedures, or characteristics of or labels for a group of classes. Next, we divided terms into classes and formulated two more tasks. One is to arrange the terms in hierarchical order (superclass, subclass), and the second task is alignment with top-level ontology (see Figure 2). A top-level ontology usually references information architecture, which enables interoperability when we need to integrate our model with others.

4.2 Design principles

An application has been developed for the health-care domain, which involves plenty of personal data. To tackle such sensitive personal information, we are using the designing principle of common data model (CDM) as suggested by Reich et al. (2017). The CDM is designed to store observational data to allow for our experiments under the following principles:

- Suitability: The CDM aims to provide data organized in a way optimal for analysis rather than for the purpose of operational needs of health care providers or payers;
- Data protection: All data that might jeopardize the identity and protection of patients, such as names, precise birthdays etc. Exceptions are possible where the research expressly requires more detailed information, such as precise birth dates for the study of infants’

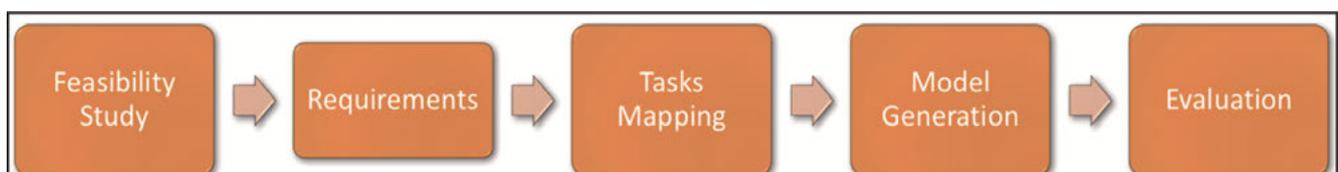


Figure 1. Steps followed to construct the ontology.

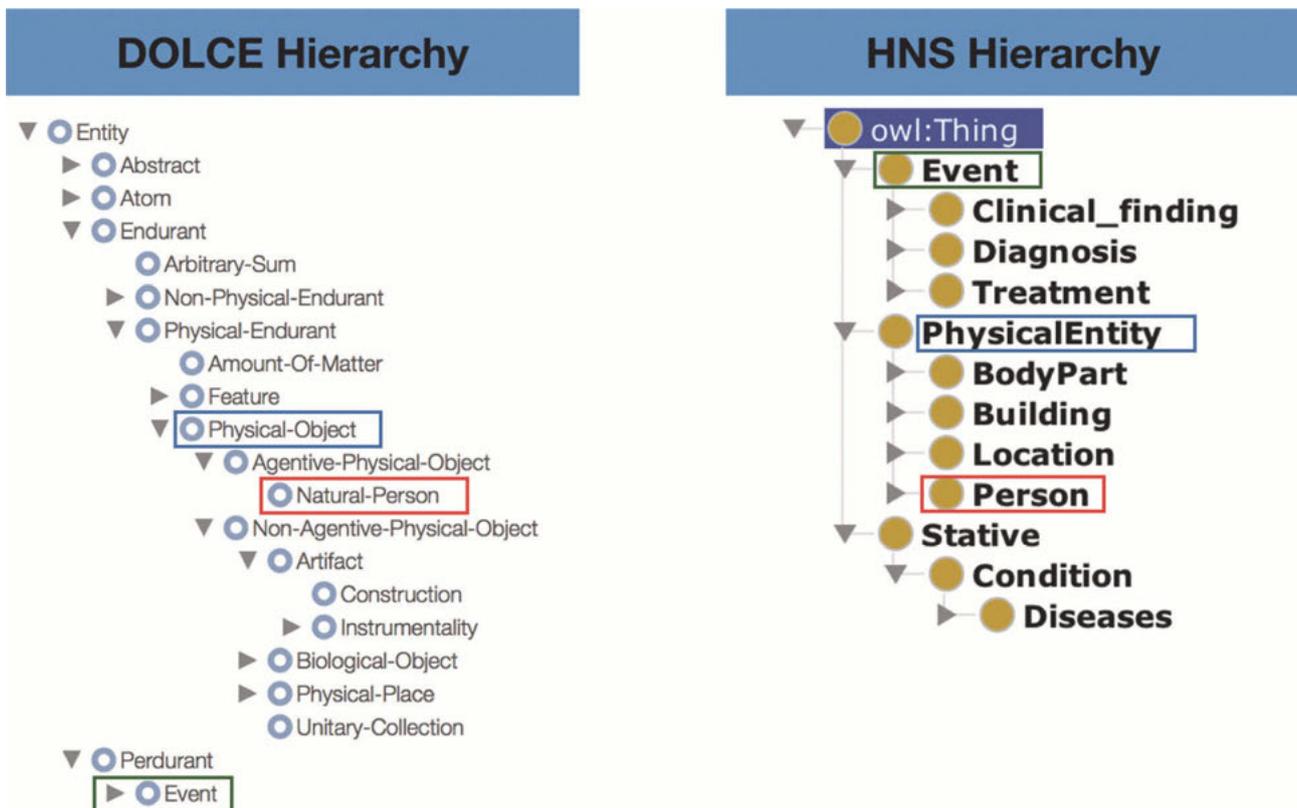


Figure 2. Alignment with the upper-level ontology.

- Design of domains: The domains are modelled in an entity-centric relational data model, where for each record the identity of the person and a date is captured as a minimum;
- Rationale for domains: Domains are identified and separately defined in an entity-relationship model if they have an analysis use case, and the domain has specific attributes that are not otherwise applicable. All other data can be preserved as an observation in an entity-attribute-value structure.
- Standardized vocabularies: To standardize the content of the records, the CDM relies on the standardized vocabularies containing all necessary and appropriate corresponding standard health-care concepts.
- Reuse of existing vocabularies: If possible, the concepts are leveraged from national or industry standardization or vocabulary definition organizations or initiatives, such as the National Library of Medicine, the Department of Veterans Affairs, the Center of Disease Control and Prevention, National Health Service, etc.;
- Maintaining source codes: Even though all codes are mapped to the standardized vocabularies, the model also stores the original source code to ensure no information is lost;
- Technology neutrality: The CDM does not require a specific technology rather than realized in any relational

database, such as Oracle, SQL Server etc., or as SAS analytical datasets;

- Scalability: The CDM is optimized for data processing and computational analysis to accommodate data sources that vary in size, including databases with up to hundreds of millions of persons and billions of clinical observations;
- Backwards compatibility: All changes from previous CDMs are clearly delineated. Older versions of the CDM can be easily created from this CDMv5, and no information is lost that was present previously.

5.0 Implementation

The best way to verify a model or a theory is through implementation. As Fernández-López, Gomez and Juristo (1997, 34) said “Obviously, if ontologies are to be used by computer, they have to be implemented.” We implemented our proposed framework through a graphical analytical platform, as shown in Figure 3. The faceted approach is adapted from the information science principle, which allows easy maintainability and encapsulation of data (entities) that will help in the creation of a high performance, generic and adaptive systems. $D = \langle E, R, A \rangle$ facet was transformed into an OWL model in such a way that it could capture its uniqueness. Whereas “entity” (E) trans-

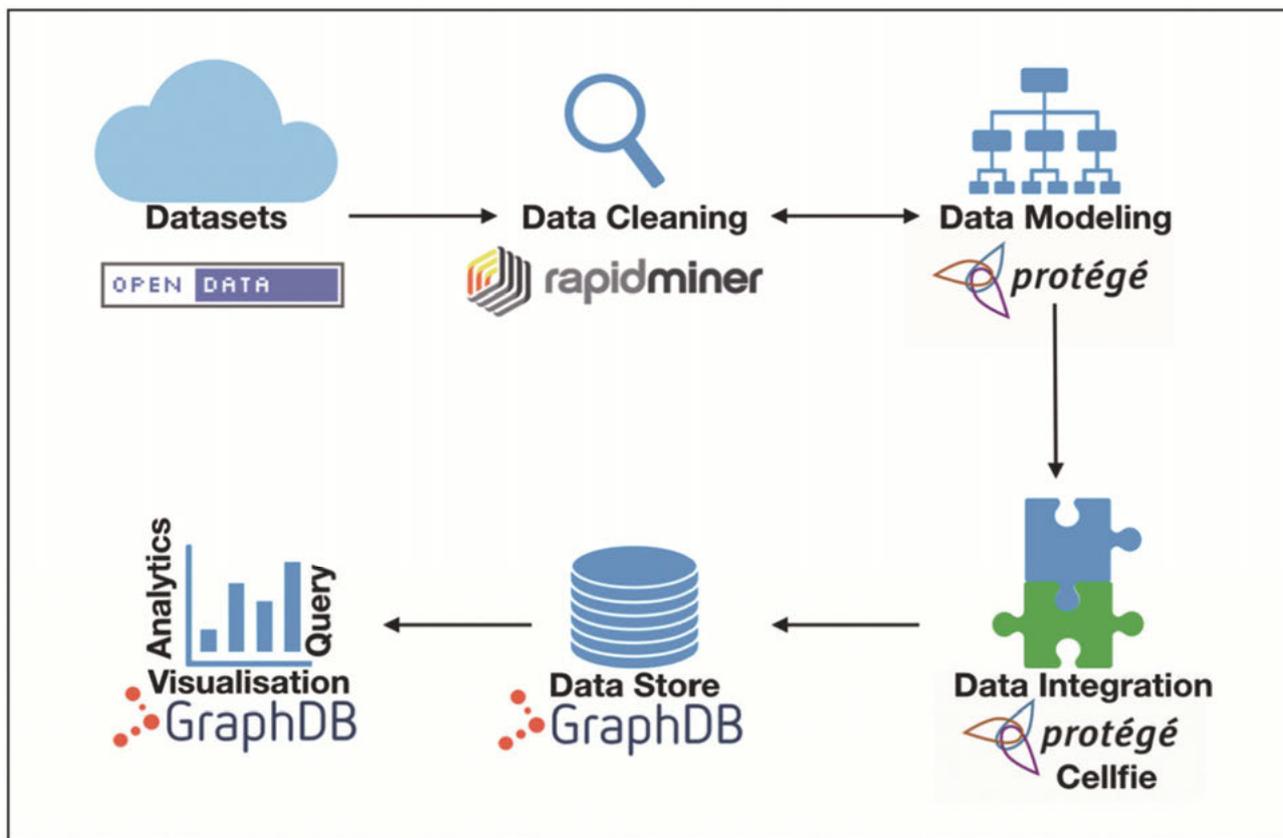


Figure 3. Implementation architecture.

form to “owl:Class,” “relation” (R) transform to “owl:ObjectProperty” and “a map” to “owl:DatatypeProperty.” For an example, in RDF/XML syntax it represents the class “clinicalFiniding” as

```
<owl:Class
  rdf:about="http://www.humannervousystem.org/KAnOE/2014/dave86#Clinical_finiding">
  <rdfs:subClassOf
  rdf:resource="http://www.humannervousystem.org/KAnOE/2014/dave86#Event"/>
  <rdfs:label xml:lang="en">Clinical
  finiding</rdfs:label>
</owl:Class>
```

It represents the relation “addressCity” as:

```
<owl:ObjectProperty
  rdf:about="http://www.humannervousystem.org/KAnOE/2014/dave86#addressCity"/>
```

And it represents the attribute “age” as”

```
<owl:DatatypeProperty
  rdf:about="http://www.humannervousystem.org/KAnOE/2014/dave86#age"/>
```

The actual implementation has been done in Protégé (<https://protege.stanford.edu>), a free, open-source ontology editor developed by the Stanford Center for Biomedical Informatics Research at the Stanford University School of Medicine. Protégé uses OWL ontologies, which are composed of three elements: individuals, properties (which are divided into object properties and datatype properties) and classes.

Individuals represent objects of the domain, whereas properties are binary relations among them. Classes (patient, doctor) are interpreted as sets that contain individuals (patient x, doctor x). Figure 4 depicts the hierarchy of HNS ontology on the left side of the figure, and on the right side, class visualization is represented using the ProtégéVOWL (<http://vowl.visualdataweb.org/protegevowl.html>) visualization tool; a Protégé plugin for the user-oriented visualization of ontologies. ProtégéVOWL implements the visual notation for OWL ontologies (VOWL) by providing graphical depictions for elements of the web ontology language (OWL) that are combined to a force-directed graph layout representing the ontology.

For analytics and query visualization, we used GraphDB (<http://graphdb.ontotext.com>) by OntoText. It is an enterprise-ready semantic graph database, compliant with W3C standards. Semantic graph databases (also called RDF triple stores) provide the core infrastructure for solutions where

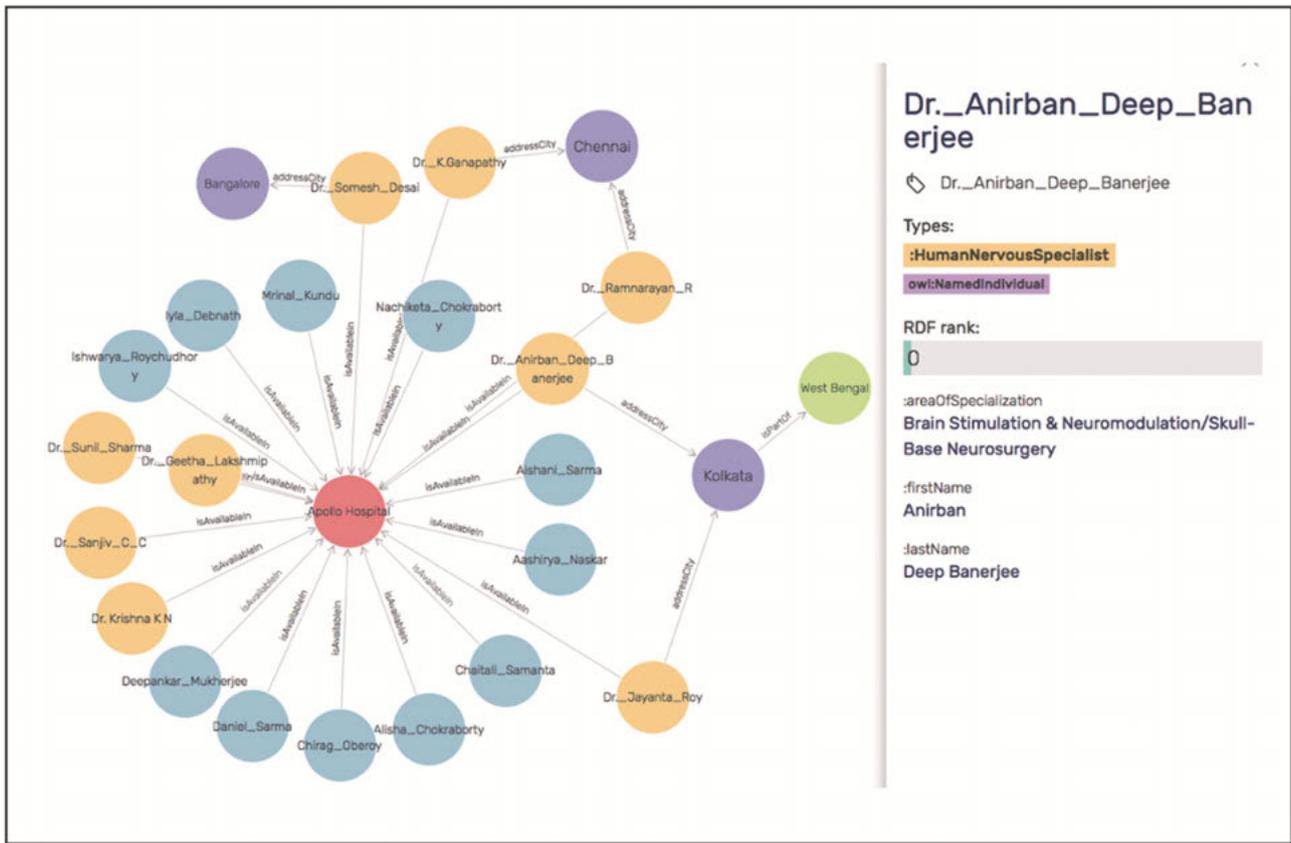


Figure 4. HNS ontology visualization.

modelling agility, data integration, relationship exploration and cross-enterprise data publishing and consumption are important.

The connected graph is the final implementation of the model in the GraphDB platform. Figure 5 depicts a snapshot of the connected graph of the HNS ontology. From Figure 5, we can easily understand how one individual (e.g., Dr. Anirban Deep Banerjee) is connected with other related entities. The same color nodes represent entities that belong to the same class, and directed arrows depict how they are connected.

6.0 Evaluation

We checked: a) syntactic correctness and consistency; b) completeness and conciseness; and, c) empirical adequacy of the developed model. Syntactic correctness and consistency are checked by means of facilities offered by Protégé, and the Hermit OWL 2 reasoner has been used to check the consistency of the model as per description logic (DL) specifications and declarations. As described in Section 4, the methodology we employed ensures that the developed model is by construction complete and concise as per required task.

The second part of the evaluation has been done in respect with the competency question (CQ). This is the one

of the best methods to evaluate medical ontologies as suggested by Abacha et. al. (2013) and Bezerra et. al. (2013). Competency queries provided the way to check the “entity” (E) facet, “relation” (R) facet and “attribute” (A) facet together, which are embedded in the form of natural language in a given question; for example, a query like “Give a list all the hospitals in x city which have facilities for the disabled.” Then from this natural language question we can derive:

- Identification of general query pattern. Give me all X in Y AND WHERE.property.True.
- Identification: Concepts and Properties. Entity: Hospital, City.
- Relation (R) addressCity: Hospital.name, City.name, and Attribute (A) facilityForDisable. Boolean

We formalized CQ according to the query language and retrieved the correct result. Example of this kind of three queries are given below:

- CQ1: Find all doctors’ names as well as the hospitals where they are available.
- CQ2: Find all doctors’ names and their specialization along with the where cities they are available.
- CQ3: Find all doctors’ names and their contact information.

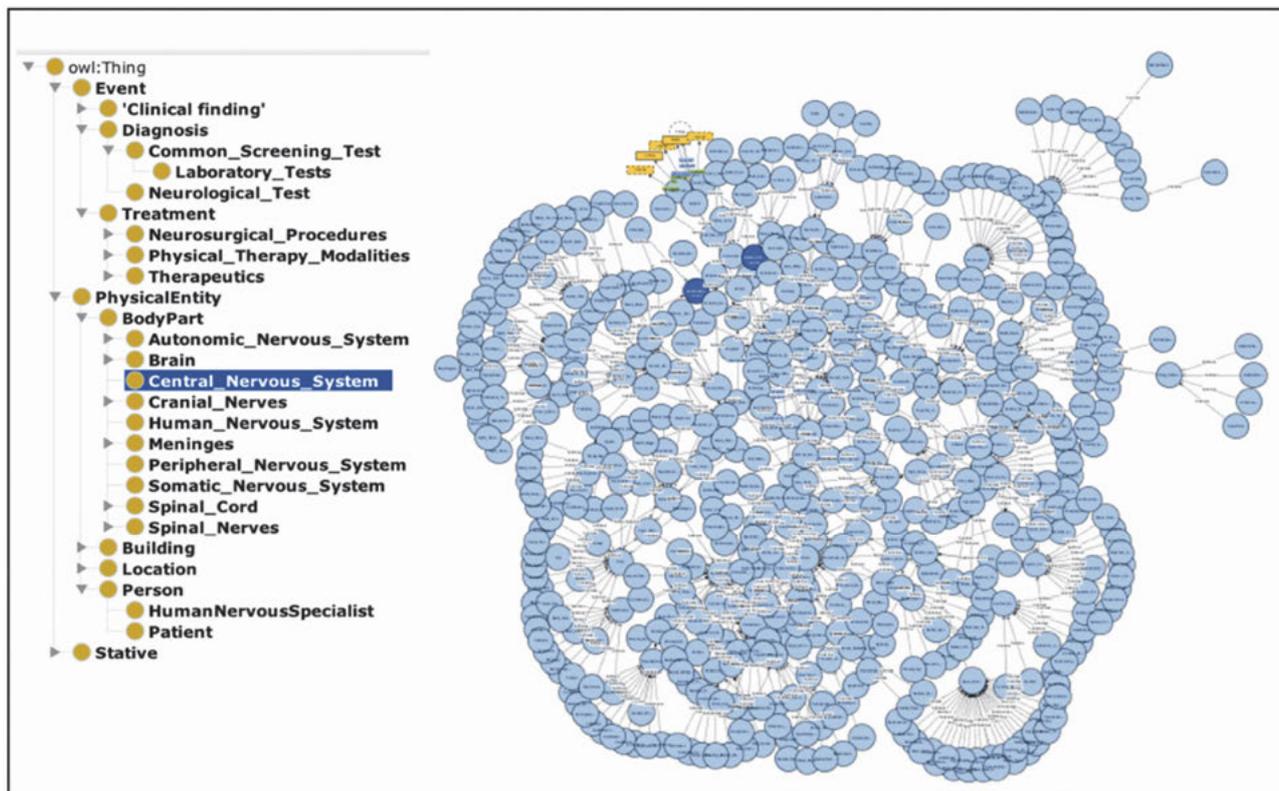


Figure 5. Connected entities.

CQ1

```

PREFIX rdf : <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl : <http://www.w3.org/2002/07/owl#> 355
PREFIX rdfs : <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd : <http://www.w3.org/2001/XMLSchema#>
PREFIX hns : <http://www.humannervousystem.org/KAnOE/2014/dave86#>
SELECT ?Doctor ?Hospital
WHERE { ?Doctor hns:isAvailableIn ?Hospital }
    
```

SPARQL query 1.

CQ2

```

PREFIX rdf : <http://www.w3.org/1999/02/22-rdf-syntax-ns#> 365
PREFIX owl : <http://www.w3.org/2002/07/owl#>
PREFIX rdfs : <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd : <http://www.w3.org/2001/XMLSchema#>
PREFIX hns : <http://www.humannervousystem.org/KAnOE/2014/dave86#>
SELECT ?Doctor ?Specialist ?City 370
WHERE { ?Doctor hns:addressCity ?City.
          ?Doctor hns:expertIn ?Specialist.}
    
```

SPARQL query 2.

CQ3

```

PREFIX rdf : <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl : <http://www.w3.org/2002/07/owl#>
PREFIX rdfs : <http://www.w3.org/2000/01/rdf-schema#>
PREFIX xsd : <http://www.w3.org/2001/XMLSchema#> 380
PREFIX hns : <http://www.humannervousystem.org/KAnOE/2014/dave86#>
SELECT ?Doctor ?PhoneNumber ?Email
WHERE { ?Doctor hns:hasContactNo ?PhoneNumber.
        ?Doctor hns : mailBox ?Email.}

```

SPARQL query 3.

7.0 Conclusion and future work

The purpose of representing active knowledge about the human nervous system (HNS) is quite important and largely advantageous. Computer-based HNS ontology supports the work of researchers in gathering information on nervous system research and allows users across the world to intelligently access new scientific information quickly and efficiently. Shared knowledge improves research efficiency and effectiveness, because it helps to avoid unnecessary redundancy in doing the same experiments or research, thereby avoiding repetition of work. We have described how we built an ontology by using a faceted classification approach to enhance the accessing and retrieving of web content. Our ontology will facilitate the exact combination of the genetic and environmental factors involved as well as their individual influence on HNS. It will be of acute help to doctors for searching patient records. Ultimately such initiative aimed towards the delivery of quality health-care service.

In the future, we wish to develop an ontology related to more specific diseases and assembled datasets from the best hospitals across different regions. This ontology will be used with a more advanced methodology to retrieve relevant and details information regarding patient records. This system will help to guide a new medical practitioner as well as laymen who seek information.

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