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NorPOnt: Creation of a domain ontology for S R Ranganathan's normative principles in library and information science

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S. R. Ranganathan formulated several rules and guidelines for classification and cataloguing, and normative principles are one among them. The present study aims to develop an ontology on normative principles (NorPOnt) so that it will improve data connection, knowledge representation, and search strategies. Protégé software was utilised to develop the ontology and the built-in Pellet Reasoner Plug-in was used to investigate for inconsistencies and found none. Competency questions (CQs) were created to measure the satisfaction level of select experts in using the ontology. The mean satisfactory level was found to be 3.24, which indicates that satisfactory and highly satisfactory were the two most common responses. The ontology's quality was also assessed using the FOCA method. After the computation, the quality value (μ) was discovered to be 0.992, which is near 1, signifying excellent quality. The evaluation results show that NorPOnt is an ontology with few inconsistencies and could answer the CQs better with higher quality.

Keywords: Ontology, Normative Principles, S.R. Ranganathan, Competency Questions (CQs), FOCA Methodology.

Introduction

The semantic web has been suggested as a web extension to enable collaboration between machines and humans[1]. It aims to enhance the services the current web provides and make it brighter[2], and for this, the needs of the consumers must be recognised, effectively communicated, and connected to the data. Ontology is a knowledge representation utilised on the semantic web[3]. It generally converts a domain into a machine-readable format that humans can also understand.

Currently, information available on the web has been designed for human understanding. Programs can be written to process, analyse, and index web pages to help humans process information[4]. However, programs cannot precisely comprehend web page contents due to the lack of machine-readable structure and knowledge representation for web documents. Hence, there is difficulty in extracting semantic information from web documents[5].

Semantic web and ontology

Semantic web services define web services as ontologies that other programs may access and comprehend[6]. They were developed in order to make the information represented by ontologies on the semantic web accessible across several applications[7]. Ontology is defined as an unambiguous, machine-readable specification of a common conceptualisation[8]. However, ontologies are useful for applications where knowledge is important and can also cause significant changes in current Web content. This transition resulted in the semantic web's third generation, which is characterised by the conceptual structuring of the web in an explicit machine-readable way[9]. Ontologies in information systems offer benefits such as improved interoperability, knowledge exchange, and data source integration[10].

Normative principles

Ranganathan's seminal work 'Prolegomena to library classification' is considered as a foundational work in library and information science[11]. It presents his influential theory of library classification, known as the Colon Classification system. In this work, he outlines his classification system based on fundamental categories that he called 'facets'. These facets include personality, matter, energy, space, and time, and they can be used to classify all types of information resources. Ranganathan's system was

intended to be adaptable to various subject areas and was designed to be flexible enough to accommodate new fields of knowledge as they emerged. This book includes normative principles and general guidelines one must remember while classifying and cataloguing documents. Under normative principles, he describes five laws of library science and six general laws.

Review of literature

The literature survey was conducted to find related papers for the present study, and popular sources like google scholar, semantic scholar, Emerald, Scopus, and Web of Science *(WoS)* were utilised for it. It was discovered that different ontologies in various domains and several ontology-building methodologies already exist. Relevant papers were selected based on different inclusion and exclusion criteria.

Fernandez, Gomez-Pérez, and Juristo[12] introduced an ontology creation process, a life cycle for building ontologies based on developing prototypes, and METHONTOLOGY, a well-structured approach for creating ontologies from the start. Brusa, Caliusco, and Chiotti[13] depicted the process and product of developing an ontology for the budgetary domain in the public sector by using the same METHONTOLOGY framework. Dutta, Chatterjee, and Madalli[14]proposed another methodology for developing ontologies called Yet Another Methodology for Ontology (YAMO). The methodology is demonstrated by building a large-scale faceted ontology for the food domain using guiding principles. Syamili and Rekha[15] described the development of an ontology for the heroes of ancient Greek mythology and religion. The paper followed a combination of different methodologies to develop the ontology, which includes the motivating scenario concept, developing cycle, and analytico-synthetic approach. Ghosh and Panigrahi[16] described the development of a domain ontology for library and information science using Ranganathan's faceted classification technique. The ontology editor Protégé was used to create hierarchical links between concepts while adhering to Ranganathan's Colon Classification.

Several tools are there for checking the syntactical correctness of an ontology, such as OOPS!, built-in reasoners (HermiT, Pellet and ELK etc.) in the Protégé software etc. And for semantical correctness, SPARQL Queries can also be utilised. In a paper, Chen, Kokar, and Moskal[17] proposed a program, SPARQL Query Generator (SQG), which can automatically be generated SPARQL queries. It generates queries about various types of descriptions of objects expressed in RDF/OWL. The intent is to use SQG in evaluating data representation and retrieval systems from the perspective of OWL semantics coverage.

A survey on checking the available tool and methods for ontology evaluation was done. A novel and matured method, FOCA, was identified. This approach was developed by authors Bandeira et al. [18] by taking three important criteria into account: i) It is empirically assessed using the Goal, Question, Metric (GQM) methodology; ii) the methods' objectives are based on the roles of knowledge representations paired with particular evaluation criteria; and iii) each ontology is evaluated according to its kind. The same for evaluating ontology was adopted in several other papers. Alsanad, Chikh, and Mirza[19] proposed a systematic domain ontology for managing requirement changes in global software development. The ontology is developed using a hybrid method and validated using the FOCA[18] methodology. Another paper proposed by Sun, Hu, Li and Wu[20] constructed an ontology called Entire Process Ontology on Software Testing (EPOST) to address the problem of knowledge silo in software testing. EPOST defines and explains the ideas and links between software testing process information, software test object information, and software defect information. The built ontology was also examined using the FOCA method in this case.

From the review conducted, despite many efforts being made to construct ontologies on various domains, only a few articles were published on generating ontologies in S. R. Ranganathan's works; thus, a research gap needs to be filled.

Objectives

- To prepare an ontology for the normative principles in library classification and cataloguing proposed by S. R. Ranganathan.
- To validate the Normative Principles Ontology (NorPOnt) by measuring the users' satisfaction level in answering the Competency Questions (CQs).
- To measure the quality of the normative principle ontology using FOCA methodology.

Methodology

Developing semantically-aware web services requires comprehensive and accurate ontologies[21]. Over the years, people from diverse fields have

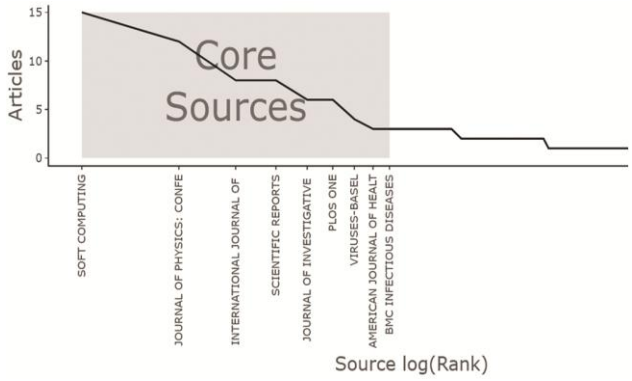

Fig. 1 — Process of ontology development

developed several systematic ontology construction methods. One cannot, however, claim that a particular approach is ideal in every circumstance. The method developed by Brusa, Caliusco, and Chiotti[13] was adapted for developing the NorPOnt in the present study, which is considered accurate and well-mature. Figure 1 depicts the steps involved in this ontology development process.The method is based mainly on METHONTOLOGY[12], which is also considered the most accurate development method in terms of IEEE standards[22]. For the development of Ontology, Protégé, an open-source software development by Stanford University, was used, and it is considered the most widely used software for building and maintaining ontologies[23]. A questionnaire was developed containing eleven CQs to check the satisfaction level among the ten selected experts. The quality level of the ontology created was measured using the FOCA[18] method. The equation for numerically calculating the quality is given below.

$$\mu = \frac{\exp\{-0.44 + 0.03(Cov_S \times Sb)_i + 0.02(Cov_C \times Co)_i + 0.01(Cov_R \times Re)_i + 0.02(Cov_{CP} \times Cp)_I - 0.66LExp_i - 25(0.1 \times Nl)_i\}}{1 + \exp\{-0.44 + 0.03(Cov_S \times Sb)_i + 0.02(Cov_C \times Co)_i + 0.01(Cov_R \times Re)_i + 0.02(Cov_{CP} \times Cp)_i - 0.66LExp_i - 25(0.1 \times Nl)_i\}}$$

Creation of NorPOnt

According to the ontology development method created by Brusa, Caliusco, and Chiotti[13] the whole ontology development process contains three phases:

- *Specification*
- *Conceptualisation*
- *Implementation*

Each phase contains further divisions through which the developmental process goes are explained below.

First Phase: Specification

Determine the ontology goal and scope

The first step is defining the scope and boundaries of the ontology to be created. It shows what needs to be included and what does not[13,22]. The authors aim to develop an ontology of normative principles in library classification and cataloguing put forward by S. R. Ranganathan and it does not consider other ideas introduced by him in the same discipline.

Describe the domain

The domain should be investigated and appropriately described to develop an ontology comprehensively. The original content of the book'Prolegomena to library classification' was thoroughly scanned for getting the concept of normative principles. Furthermore, to get a deep understanding, other books and academic papers written on the same were read carefully to get a picture of the knowledge domain.

A group of experts containing research scholars, students, professionals, and professors of the Library and information science domain were identified to clarify the further doubts. Discussions with them were carried out to get a holistic view of S. R. Ranganathan's principles. The same group was utilised while evaluating the ontology and competency question (CQ) formation.

The normative principles include the Five laws of library science and the six General laws.A short description of the domain is given here. Five laws of Library science are stated below.

1. Books are for use
2. Every reader his/her book
3. Every book its reader
4. Save the time of the reader
5. Library is a growing organism

Each of these laws has several implications and is considered the pillar of the discipline of library and information science. The six general laws are:

1. Law of interpretation
2. Law of impartiality
3. Law of symmetry
4. Law of parsimony
5. Law of local variation
6. Law of osmosis

The law of impartiality deals with the fair usage of heading entries while cataloguing. The law of interpretation deals with interpreting Classified Catalogue Code (CCC). It suggests treating it as a

legal document and interpreting it like that. The law of symmetry deals with equal treatment of entity counterparts. Next, the law of parsimony advocates to maximum utilisation of resources (time, energy, manpower). The law of local variation gives provision to local variation. These are important in multilingual texts. The law of osmosis suggests changing the strategies and schemes according to the changes happening around the universe[11].

Motivating scenarios and competence questions

The whole idea of the motivating scenario is the rise of the need for information unavailable in the domain. Besides, the scenario description contains a set of solutions to these problems, including the semantic aspects of solving them[13]. Motivating scenarios are the story problems or examples which are not adequately addressed by existing ontologies. Templates have been used to define motivating scenarios and communicate them to the involved people. These templates were based on those proposed to specify case uses in object-oriented methodology[24]. Table 1 describes the motivating scenarios for the possibility of the development of NorPOnt.

Competency Questions (CQs)

From motivational scenarios, competency questions (CQs) are derived. This enables the determination of the ontology's scope to determine if it contains sufficient information to answer these queries and the level of detail required for the responses. A concept must not be included if it is not used in a competency question. This rule is also used to determine whether an axiom is required for the ontology. In addition, CQs permit the definition of a hierarchy, so that a response to one question can also be a response to others with a broader scope by means of composition and decomposition processes[13]. Writing multiple CQs is an essential step, particularly during the specification phase[24]. They are crucial to the validation phase of the developed ontology. The evaluation-focused CQs are listed in Table 2.

Ontology granularity and type

Types of ontologies include upper ontologies, mid-level ontologies, domain (low-level) ontologies, and application ontologies[25,26]. Since the NorPOnt deals with terms and concepts related to a particular domain (normative principles for library classification and cataloguing) it comes under domain ontology.

Second Phase: Conceptualisation

Domain conceptual model

In the first step of the conceptualisation phase, all the concepts and their relations were collected from the main source Prolegomena to Library Classification, and other the books and articles were also closely examined to get maximum data for the development of the NorPOnt. Further, a table of key terms with their description and type was formulated.

Table 1 — Motivating scenarios for creating NorPOnt

Scenario: Development of Normative Principle Ontology(NorPOnt)

Actors: People involved in classifying and cataloguing documents

Description: Here, the scenario proposed is a person who wants to Classify and Catalogue Documents for the library. For this, he must go through the Classification schemes and cataloguing Code. Apart from that, a guiding principle should be there. It acts as the backbone of the quest. The Normative Principle, put forward by S. R. Ranganathan through his works does this job.

Terms: Normative Principles, Five Laws of Library Science, General Laws of Library Science, Prolegomena to Library Classification, S. R. Ranganathan

Table 2 — Competency Questions

Competency Question (CQ) Number	Competency Question (CQ)
CQ1	Normative Principles in Library Classification and Cataloguing are written by whom?
CQ2	Normative Principles of Library Science were included in which book?
CQ3	What are the five laws of Library Science?
CQ4	What are the general Laws of Library Science?
CQ5	Law of Impartiality in Library Science deals with which idea?
CQ6	Law of Symmetry in Library Science deals with which idea?
CQ7	Law of Parsimony in Library Science deals with which idea?
CQ8	Law of Interpretation in Library Science deals with which idea?
CQ9	What are the main principles in Normative Principles?
CQ10	The principle of Local Variation in Library Science is related to which idea?
CQ11	The principle of Osmosis in Library Science is related to which idea?

Table 3 — Data dictionary of NorPOnt

Key Term	Description	Type
Normative Principles	Normative Principles are the guiding principles in Library Classification and Cataloguing, put forward by S. R. Ranganathan	Concept
Five Laws of Library Science	The five laws of Library science are the fundamental Laws of Library science.	Concept
Basic Laws of Library Science	Basic Laws of Library Science are the Laws which govern the process of thinking while Classifying and Cataloguing.	Concept
Law of Local Variation	The law of Local variation suggests each Catalogue code has a local variation provision.	Concept
Law of Osmosis	The Law of Osmosis suggests adjusting to the changes in the Classification scheme and Cataloguing Code changes.	Concept
Law of Interpretation	The law of Interpretation suggests considering Classified Code as a legal document and interpreting it as a legal text.	Concept
Law of Parsimony	The Law of Parsimony suggests reducing the money, workforce and time in classification and cataloguing.	Concept
Law of Impartiality	Law of Impartiality deals with the selection of Heading entry	Concept
Law of Symmetry	The Law of Symmetry suggests that each counterpart of an entity should be treated equally.	Concept

Table 3 shows a part of data dictionary created using the information gathered from different sources.

Instance definition

The last step in the conceptualisation phase is the definition of instances for the ontology classes. But in NorPOnt instances are not defined as it is not necessary to define them[27]. Instances are particular examples of a class that may be used to represent real-world objects or things inside a domain. However, instances can add complexity to ontologies and may not be required in all cases. Instances should be included in an ontology based on the ontology's purpose and the domain it represents. In certain circumstances, it may be preferable to represent entities only using classes and attributes[27].

Third Phase: Implementation

Implementation of the ontology

In this first step of Implementation phase, the proposed NorPOnt is made reality in OWL language using Protégé version 5.6.1 software. Using inbuilt reasoners (Pellet) it was made sure that there was no mistakes or inconsistency and the developed NorPOnt. It consists of 186 axioms allocated as 54 classes and 12 object properties. Table 4 gives the detailed metrics of the NorPOnt developed.

Figure 2 gives the total object properties created in this ontology. Figure 3 shows the developed ontology root map, depicted using OWLviz, an ontology visualisation plug-in in Protégé software and Figure 4 is the Class hierarchy followed in the ontology created.

Ontology validation

The first step in ontology validation is to validate the content. Using the Pellet Reasoner Plug-in

Table 4 — Metrics of the developed NorPOnt

Item	Count
Axiom	186
Logical axiom count	120
Declaration axioms count	66
Class count	54
Object property count	12
Data property count	0
Individual count	0
Annotation Property count	1

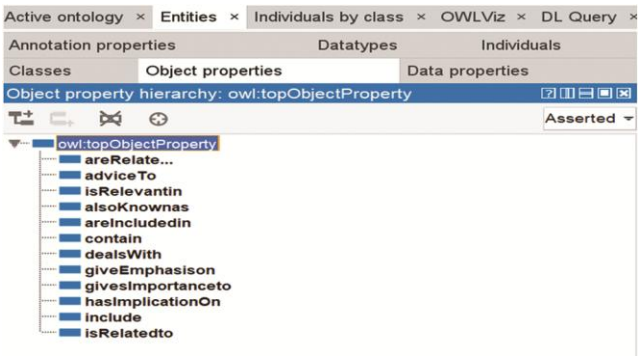

Fig. 2 — Object properties in NorPOnt

(version 2.2.0), the internal consistency was checked, and no inconsistency was found. The second approach in the validation process is checking whether the ontology was able to answer the CQs. It is a typical way to evaluate ontologies from the user's perspective, which was systematically presented by Syamili and Rekha[15]. A modified version of the same method will be adopted here, also. Because the contents for the creation of NorPOnt are purely topical, the evaluation was conducted by a group of ten experts from the field of Library and Information Science. The assessors' understanding of normative principles differed. The user comments and ideas

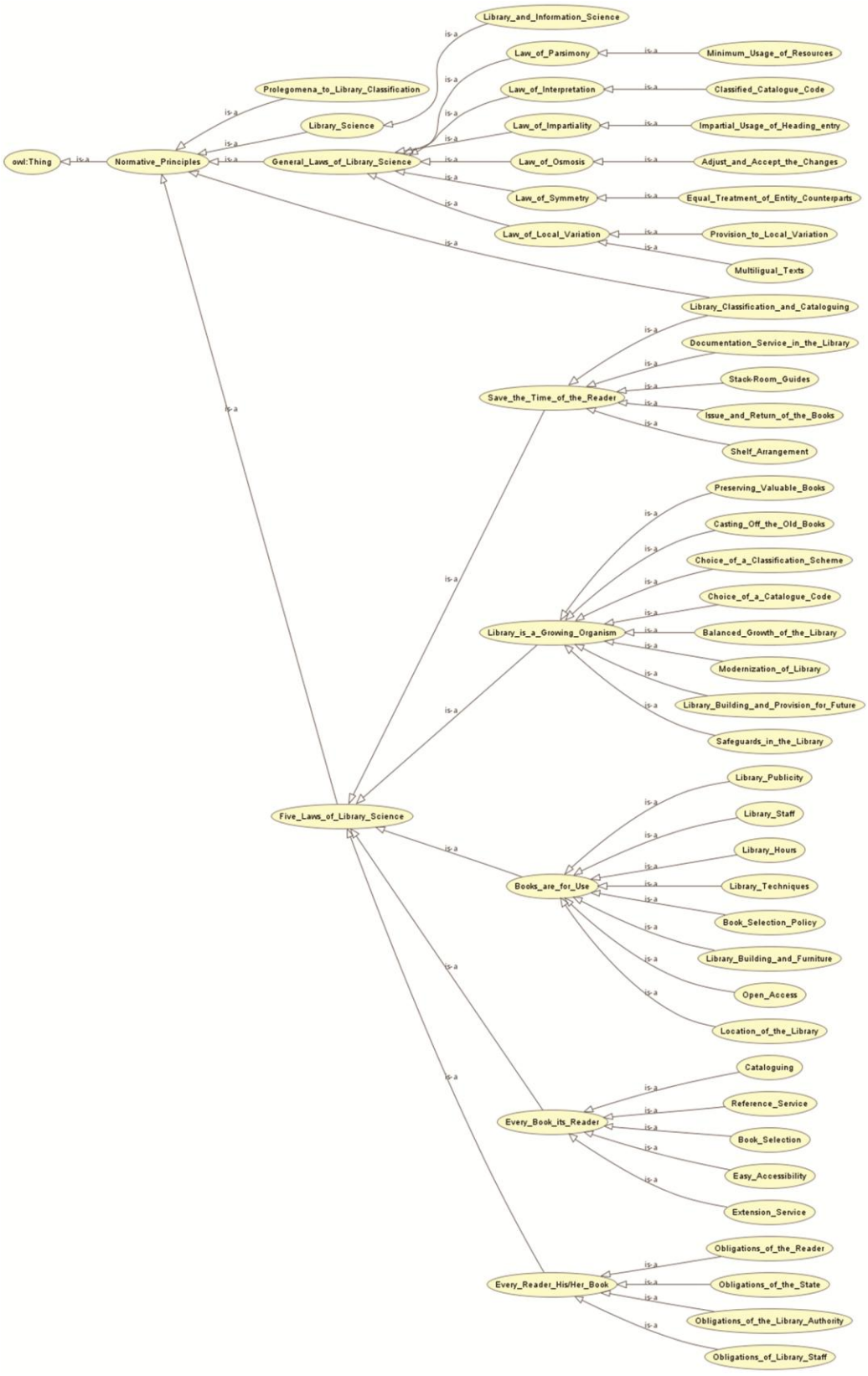

Fig. 3 — NorPOnt root map

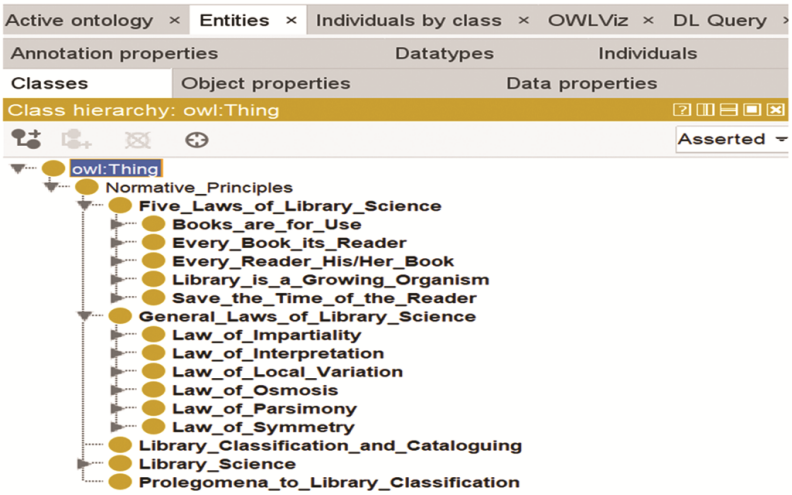

Fig. 4 — Class hierarchy of the NorPOnt

Appendix I — Evaluator's satisfaction level in answering CQs

CQ	Evaluator 1					Evaluator 2					Evaluator 3					Evaluator 4					Evaluator 5					Evaluator 6					Evaluator 7					Evaluator 8					Evaluator 9					Evaluator 10				
	HS	S	N	D	HD	HS	S	N	D	HD	HS	S	N	D	HD	HS	S	N	D	HD	HS	S	N	D	HD	HS	S	N	D	HD	HS	S	N	D	HD	HS	S	N	D	HD	HS	S	N	D	HD	HS	S	N	D	HD
CQ1		✓					✓					✓					✓				✓					✓					✓					✓					✓								
CQ2		✓					✓					✓					✓					✓					✓					✓					✓					✓								
CQ3		✓					✓					✓					✓					✓						✓				✓					✓					✓								
CQ4	✓							✓					✓					✓					✓						✓			✓					✓					✓								
CQ5	✓							✓					✓					✓					✓					✓					✓					✓					✓								
CQ6		✓					✓					✓					✓					✓						✓				✓					✓					✓								
CQ7		✓					✓					✓					✓					✓					✓					✓					✓					✓								
CQ8		✓					✓					✓				✓						✓					✓					✓					✓									✓				
CQ9		✓					✓					✓				✓						✓					✓					✓				✓	✓					✓								
CQ10		✓					✓					✓				✓						✓					✓					✓					✓					✓								
CQ11		✓					✓					✓				✓						✓					✓					✓					✓						✓								

Table 5 — Mean satisfactory level of evaluators on answering CQs

Evaluator	**Satisfactory Level (Mean)**
1	3.18
2	3.54
3	3.45
4	3.27
5	2.64
6	3.18
7	3.64
8	3.27
9	3.18
10	3.09
Total	**3.24**

were gathered. They prepared 15 questions. Four of them were clubbed to the main set as it was repeating. The final set of CQs comprises 11 questions. Later, the full normative principle ontology was sketched on chart paper. The participants were given a five-point scale questionnaire to complete in order to determine their degree of satisfaction in answering each of the CQs with the help of the chart paper. Response of the experts to each of the CQs are include in the Appendix I.

By assigning 0 to 4 values for each satisfaction level, [0 for Highly-Dissatisfied (HD), 1 for Dissatisfied (D), 2 for Neutral (N), 3 for Satisfied(S), 4 for highly satisfied (HS)] a mean satisfactory level for each evaluator was calculated. Table 5 gives the details of mean satisfactory level of evaluators.

It was found that the total satisfaction level of the developed ontology was 3.24, a value that comes in between three (Satisfied)and four (Highly-Satisfied).

Ontology verification

For verification of the NorPOnt, the FOCA method was utilised. Using a statistical model, this method helps ontology developers assess the quality of their

Table 6 — Ontology quality verification using FOCA methodology

Goal	Question	Metric	Grade	Mean
1.Check if the ontology complies with Substitute	Q1. Were the competency questions defined?	1. Completeness.	100	58.33
	Q2. Were the competency questions answered?	1. Completeness.	75	
	Q3. Did the ontology reuse other ontologies?	2. Adaptability.	0	
2. Check if the ontology complies Ontological Commitments.	Q4. Did the ontology impose a minimal ontological commitment?	3. Conciseness.		58.33
	Q5. Did the ontology impose a maximum ontological commitment?	3. Conciseness.	75	
	Q6. Are the ontology properties coherent with the domain?	4. Consistency.	100	
3. Check if the ontology complies with Intelligent Reasoning	Q7. Are there contradictory axioms?	4. Consistency.	100	100
	Q8. Are there redundant axioms?	3. Conciseness.	100	
4. Check if the ontology complies Efficient Computation	Q9. Did the reasoner bring modelling errors?	5. Computational efficiency.	100	100
	Q10. Did the reasoner perform quickly?	5. Computational efficiency.	100	
5. Check if the ontology complies with Human Expression.	Q11. Is the documentation consistent with modelling?	6. Clarity.	0	33.33
	Q12. Were the concepts well written?	6. Clarity.	100	
	Q13. Are there annotations in the ontology that show the definitions of the concepts?	6. Clarity.	0	

From the tabular data, the quality (μ)can be calculated.

ontologies. Here, the reliability of the created ontology is evaluated. There are two distinct types of quality control, total and partial verification. Total quality verification was chosen for the NorPOnt because the ontology quality in this method considers all five roles of knowledge representation: substitute, ontological commitments, intelligent reasoning, efficient computation, and human expression[22]. Using beta regression model[29], the aggregate quality verification, which ranges from 0 to 1, was determined. The outcomes are listed below. Table 6 displays the mean grade for each of the five knowledge representation positions.

$$\mu = \exp\{-0.44 + 0.03(Cov_S \times Sb)_i + 0.02(Cov_C \times Co)_i + 0.01(Cov_R \times Re)_i + 0.02(Cov_{CP} \times Cp)_I - 0.66LExp_i - 25(0.1 \times Nl)_i\}$$

$$1 + \exp\{-0.44 + 0.03(Cov_S \times Sb)_i + 0.02(Cov_C \times Co)_i + 0.01(Cov_R \times Re)_i + 0.02(Cov_{CP} \times Cp)_i - 0.66LExp_i - 25(0.1 \times Nl)_i\}$$

Here the μ value is 0.992, which is very close to 1. It shows that the quality of the NorPOnt ontology is very high.

Conclusion

The role of ontologies in the development of the semantic web is self-explanatory. The current work intended to develop an ontology based on the normative principles proposed by S. R. Ranganathan. These standards are the guiding principles for anybody undertaking library classification and cataloguing. It will benefit people who want to develop a recommendation or e-learning system based on Normative Principles. The ontology was successfully built following the technique proposed by Brusa, Caliusco, and Chiotti[13]. The ontology in OWL language was created using Protégé (version 5.6.1). The created Normative Principle Ontology (NorPOnt) has 186 axioms organised into 54 classes and 12 object attributes. The built-in Pellet Reasoner Plug-in (version 2.2.0) was used to investigate for inconsistencies and found none. Competency questions were developed for the NorPOnt's assessment. From the user's point of view, the ontology's satisfaction level was determined. For this objective, a ten-person expert committee was formed. The mean satisfactory level was found to be 3.24, which indicates that Satisfactory and Highly Satisfactory were the two most common responses. The ontology's quality was also assessed using the FOCA[18] approach. After the computation, the quality value (μ) was discovered to be 0.992, which is near 1, signifying excellent quality. Overall, the project was a success in terms of developing NorPOnt and testing its validity and quality.

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