Ontology Rules for Library Research Services Recommendation System

Yuwapa Ruger, Malee Kabmala, and Wirapong Chansanam

***Abstract*—This research aims to present the design and construction of guidelines on the ontology rules for research support services of the Khon Kaen University Library. In this research, there was a usage of Protégé version 3.5 to build an ontology into a knowledge base in the form of Ontology Web Language (OWL). The results showed ten ontology rules: 1) Rules for plagiarism recommendations 2) Rules for plagiarism recommendations on journal quality audits for academic publications 3) Rules for displaying recommendations on information retrieval in Web OPAC 4) Rules for displaying recommendations for information literacy training programs 5) Rules for displaying recommendations on thesis database lists 6) Rules for displaying recommendations 7) Rules for displaying instructions on e-journals databases, 8) Rules for displaying instructions on citations in the next section, 9) Rules for displaying instructions on endnote citations, and 10) Rules for displaying advice on research aids. The measurement accuracy (Precision) was 92.73%, the completeness (Recall) was 90.74%, and the F-measure was 91.72%.**

***Index Terms*—Ontology rules, library research services, recommendation system.**

I. Introduction

Khon Kaen University is a national research university. Therefore, the Khon Kaen University Library must focus on the procurement and service of various forms of information resources to fulfill the university's mission, leading to students' production and development. In addition, they develop services to support researching, teaching, and learning according to the curriculum of teachers and students. Providers must supply research support services to comply with the university's determination to support the use of research results for the benefit of the community. It is also the primary educational and research infrastructure [1]. These activities are all part of the driving force of Khon Kaen University to be a university of learning [2], [3]. However, they still experience problems or impacts from serving while doing so. Many users found the problem with library services advice. These caused them to submit questions from various channels, such as inquiries via Chatbot, Facebook pages, Emails, LINE applications, Online forms, etc., especially the research user group. This group of users has similar needs, such as access to in-depth academic resources for research purposes and teaching according to each field of study to which it belongs or according to its research content. The question format librarians receive is often repetitive, making them suggest the same answers. This results in a redundant task—a loss of time in performing other tasks. Or sometimes, librarians may be performing other tasks, causing them not to be able to advise users immediately. This service delay may affect the agency's level of satisfaction and image.

The Office of the Library at Khon Kaen University collected 5,561 questions asked by users through various contact channels from 2015 to 2019, which were repetitive. The problem mentioned above points out the importance of the problem with the library's handling of questions, including the introduction of questions to develop ontology techniques.

Ontology is a technique used to represent reusable knowledge in the Knowledge Management (KM) field for several purposes, such as corporate memories, interoperability of databases through a common ontology, etc. Therefore, results in ontology creation are of use for KM. The ontology can bring outcomes for sharing and reusing this body of knowledge. Rules and ontology play important roles in the layered architecture of the Semantic Web as they are used to ascribe meaning and reason to data on the Web. Many implementations of rule engines deal with semantic web data in one way or another. The ontology rules created in this study can bridge the gap between ontology and relational data models to generate specific search requests using ontology. Moreover, ontology-based information retrieval provides a reference for enhancing the searching capabilities of massively loaded recommendation systems.

The design and development of ontology transform knowledge into a form that humans and computers can understand. These allow the software to share or bring ontology for processing together. There are several development methods for designing and developing an ontology [4]. In this article, the methods are as follows:

Sugumaran and Storey [5] present a method for developing an ontology that can be divided into four steps as follows:

1) Define a generic term for creating an ontology, including defining synonyms
2) Determine the relationship between those terms: general relationship (Is-a), synonym relationship, and related word relationship
3) Determine the conditions of the initial relationship, such as the relationship that will occur or cannot happen if any other relationship precedes, and
4) Set high-level conditions such as Domain & Range

Noy and McGuinness [6] present a more detailed methodology for designing and developing an ontology from Sugumaran and Storey. Noy and McGuinness design seven steps, including:

1) Consider the scope and objectives of the ontology
2) Check an existing ontology

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3) Determine terms used in ontology
4) Define the vocabulary that is a class type (Classes)
5) Define the word relationship type
6) Define class and relationship conditions such as Default Value, Cardinality, domain and range of relationship, etc., and
7) Create Instances to use as knowledge for processing

Staab *et al.* [7] present an approach similar to Noy and McGuinness [6] but reduce the number of steps and increase the life cycle in an ontology design and development approach. Staab *et al.* provide five steps, including: a) Study the possibility of developing ontology. It is an analysis of problems and methods for implementing ontology. b) Define and document the requirements of ontology which contain details such as the objectives of the ontology scope and domains, sources of knowledge, users, and competency questions for determining the ontology's ability to answer questions, etc. c) Collect knowledge and build the ontology. This step defines concepts, relationships, and conditions in the ontology. d) Ontology testing procedures. Initially, the developer must verify if there is documentation of the ontology requirements. Moreover, check if the designed ontology can answer the fundamental questions set forth, including allowing users to check the satisfaction of the ontology structure. From this step, developers can edit step 3 and the last step. e) Improvement and maintenance of ontology. Knowledge is subject to change over time and therefore needs to be monitored to improve and correct information.

Therefore, in this research, the development of a consulting ontology for research support services of the Khon Kaen University Library is studied. The development of a knowledge-based ontology structure will be a useful guideline for developing a recommendation system or an automatic answering system to help reduce the librarian's workload and assist researchers in researching or accessing the services the library has provided. This research focuses on the design and development of the guidance ontology rules for the Khon Kaen University Library research support services, which will be discussed in the next section.

II. Methodology and Results

We are designing Recommendations Ontology Rules for Research Support Services of the Khon Kaen University Library. It is a continual step from developing a research support service advisory ontology, using Protégé[8] as a tool for developing ontology in conjunction with designing rules, defining instructions, and creating an additional instruction class as a conditional hint element in the Semantic Web Rule Language (SWRL) [9]. To create a conditional inference rule with SWRL, there is a conditional clause, class name, and instance. The data used to design rules in conjunction with SWRL requires Roman characters. Therefore, the system understands the commands and can retrieve information. The design of the ten pre-guided rules for research support services is shown in Fig. 1. The rules design details are as follows:

1) Protégé design rules or conditions for displaying recommendations
2) A simulation of the rendering of web application suggestions with WebProtégé
3) Performance assessment using Information Retrieval (IR)

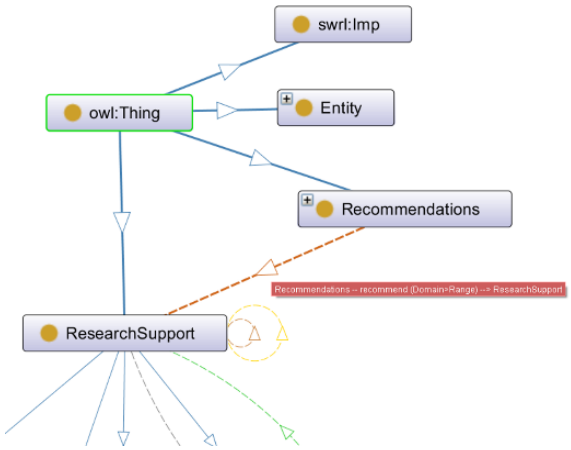

Fig. 1. SWRL-language instruction rule design.

This research uses the Protégé program to develop ontology in conjunction with rules and conditions for displaying recommendations by creating an additional instruction class to serve as a conditional section.

By designing rules for writing conditional inference in SWRL language, the ten introductory rules are outlined in detail on how to design and create a rule. It is necessary to use Roman characters to define the class names. Additionally, with the use of snippets and the rules designed in SWRL, the system understands the instructions and retrieves the data.

A. Protégé Design Rules or Conditions for Displaying Recommendations

1) Designing information literacy guidance rules

Designing rules to introduce what you should know about academic plagiarism by executing an SWRL statement for the system to retrieve data from the class as "How to avoid," "verification," "meaning," and "characteristics of academic plagiarism," and displaying recommendations at Object Properties: recommending and question_plagia instead of a group of questions about plagiarism of academic works, as shown in Fig. 2.

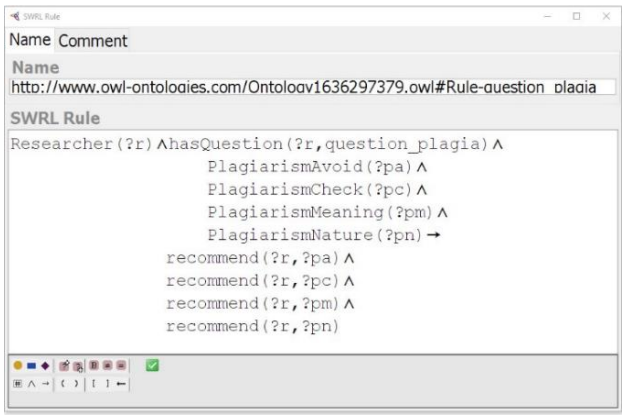

Fig. 2. Rules for displaying recommendations on academic plagiarism.

Designing rules to recommend journal quality checks for publication of academic results by executing an SWRL statement for the system to retrieve data from the class as "Quality inspection of foreign journals for publication" by fetching data from subclass "How to Check Journal Scorecards" and subclass "How to Check Journal Rankings."

The system retrieves data from subclasses for the results of the quality inspection of journals in Thailand for publication as "Group Journal 1" and subclass "Group Journal 2" to display at Object Properties: recommending and creating the question_journal check instance instead of a group of questions about the quality inspection of journals for publication of academic results, as shown in Fig. 3.

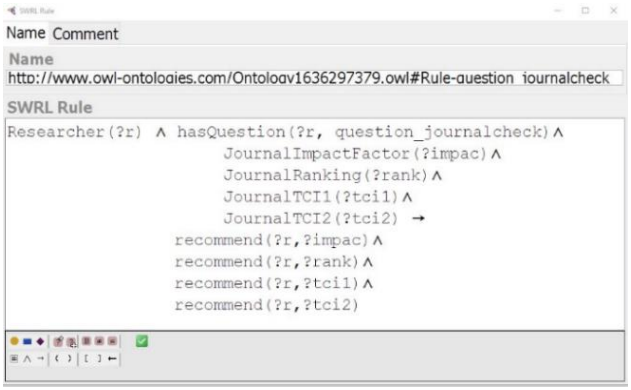

Fig. 3. Rules for displaying recommendations on journal quality audits for academic publications.

Designing rules to suggest information retrieval in Web OPAC by writing SWRL statement for the system to retrieve data from classes as "Word Search," "Author Search," "Title Search," "Subject Search," "Noun Search Example," "Author Search Example," "Author Search Example," "Title Search," and "Subject Snippet Example" to display at Object Properties: recommending and creating the question_opac instance instead of a group of questions about searching for information in Web OPAC, as shown in Fig. 4.

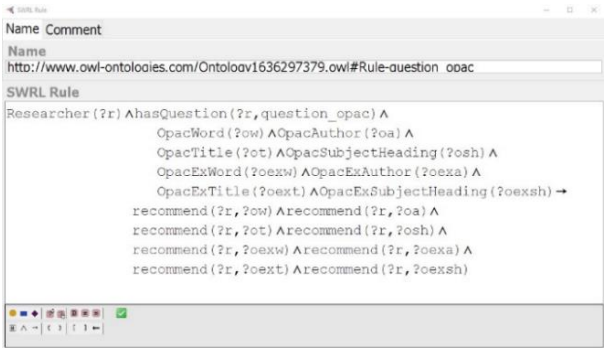

Fig. 4. Rules for displaying recommendations for information browsing in Web OPAC.

Designing rules to introduce information literacy skills training program by executing an SWRL statement for the system to retrieve data from the class, creating a question_il instance instead of a group of questions about the Information Literacy Training Program, as shown in Fig. 5.

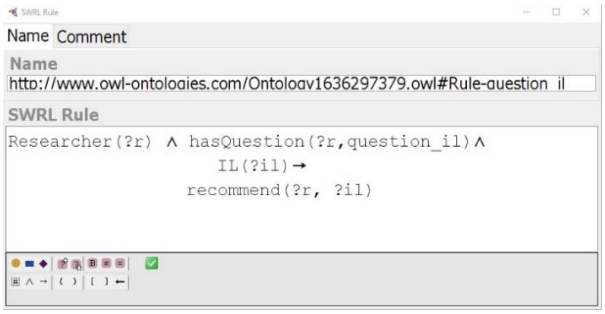

Fig. 5. Rules for displaying advice on information literacy training programs.

2) Designing rules for introducing digital information

Designing rules to introduce the thesis database by executing an SWRL statement for the system to retrieve data from the class as "Electronic Thesis Database" to display recommendations at Object Properties: recommending and creating a question_database thesis instance instead of a group of thesis database questions, as shown in Fig. 6.

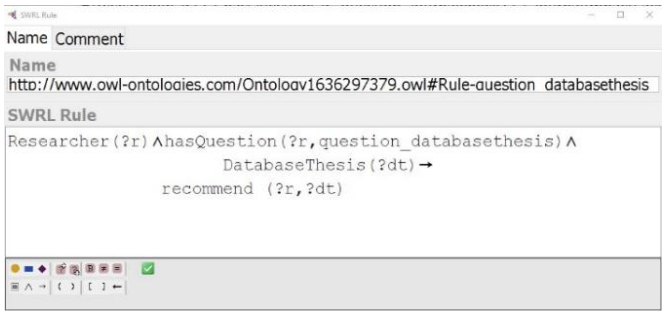

Fig. 6. Rules for displaying recommendations related to the thesis database list.

Designing rules to introduce e-books by executing an SWRL statement for the system to retrieve data from the class as "General category books," "History," "Philosophy," "Language," "Literature," "Science," "Religion," "Arts and Culture," "Social Sciences," and "Technology" category to display results and recommendations at Object Properties: recommending and creating a question_ebook instance instead of the e-book database question group, as shown in Fig.7.

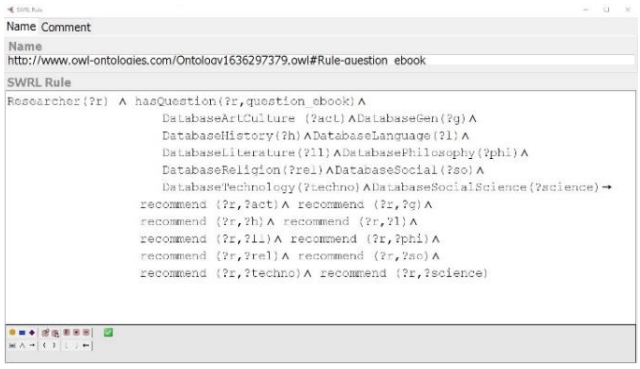

Fig. 7. Rules for displaying instructions on e-book databases.

Designing rules to introduce electronic journal databases by executing an SWRL statement for the system to retrieve data from the class at Object Properties: recommending instead of the electronic journal database question group, as shown in Fig. 8.

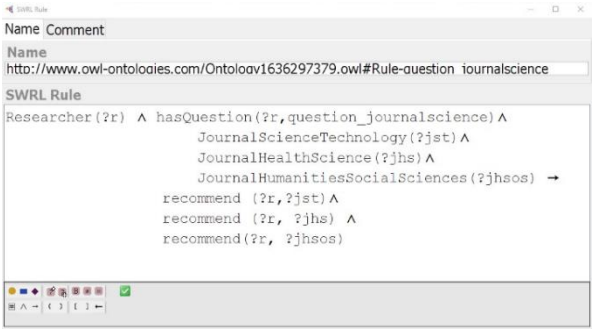

Fig. 8. Rules for displaying instructions on electronic journal databases.

3) Designing rules for recommending information for

reference and research

Designing rules to suggest document references in the text section by writing an SWRL statement for the system to retrieve data from the class as "author_name citation style followed by the year of publication," and the "numbered citation style" and render suggestions at Object Properties: recommending and creating a question_citation instance instead of a group of questions referring to the document in the subject section, as shown in Fig. 9.

Fig. 9. Rules for displaying instructions on citations in the text section.

Designing rules to suggest references at the end of the book by executing an SWRL statement for the system to retrieve data from the class as "End out Reference_APA Format" and "End out Reference_Vancouver_Style" to display recommendations at Object Properties: recommending and creating a question_bibliography instance instead of the group of questions referring to the document at the end of the book, as shown in Fig. 10.

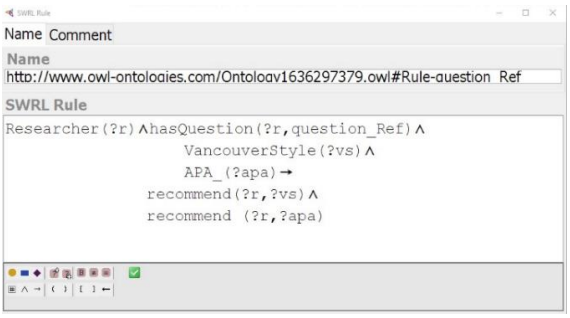

Fig. 10. Rules for displaying instructions on citations at the end of the book.

4) Designing rules for recommending research tools

Designing rules to suggest research tools by executing an SWRL statement for the system to retrieve data from the class as "Academic plagiarism checker," "English grammar checker," and "bibliography and citation management tool" to present recommendations at Object Properties: recommending and creating a snippet question_tool instance instead of a group of questions about research tools, as shown in Fig. 11.

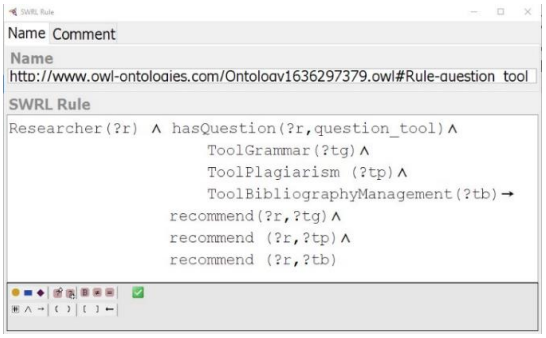

Fig. 11. Rules for displaying instructions on research aids.

Fig. 12 is an example of the knowledge structure of the established ontology rules in the Ontology Web Language (OWL) format.

Fig. 12. An example of OWL developed with Protégé.

B. A Simulation of the Rendering of a Website-Style Suggestion with WebProtégé

Simulation rendering of recommendations is conducted on a web application format. An application operates it in conjunction with WebProtégé, open source at no cost. It was developed by the Protégé team at Stanford University School of Medicine (Stanford center for biomedical informatics research) to share spaces during the development environment that is easy to develop ontology. An ontology can be shared through online platforms or even uploaded as OWL, XML RDF, Turtle, OBO, or any other file type developed from the ontology process. There is a function for other contributors to comment on the ontology developer through a class, property, or snippet. A notification will be sent to the creator's email address [10]. The system has the following display details.

1) xDisplay of recommendations for researchers based on rule design

In this research, we chose a model to create a system by uploading OWL files developed from the Protégé tool to WebProtégé, therefore, users can find them. The system contains 20 recommendations that are defined with rules or conditions, including; "Knowledge about plagiarism in academic papers," "Thesis database," "Information Literacy Skills Training Program," "Methods Check foreign journals for publication," "Journal database list," "List of journals for publication," "How to search for information," "E-book," "Research aids," "Techniques Retrieved on Web OPAC," "List of TCI Group 1 Journals for Publication," "List of TCI Group 2 Journals for Publication," "List of TCI Group 1 Journals for Publication in Humanities and Social Sciences," "List of TCI journals group 1 for publishing science and technology disciplines," "TCI journals group 1 for health sciences publications," "TCI journals group 2 for publishing groups of humanities sciences and technology Social Sciences," "List of TCI Group 2 Journals for Publishing Science and Technology Subject Groups," "List of TCI Group 2 Journals for Publishing Health Sciences Groups," "Reference Format for Endnotes," and "Writing style," as shown in Fig. 13. An example of a recommendation for a list of TCI journals group 1 is a Humanities and Social Sciences section to publish the results, as shown in Fig. 14.

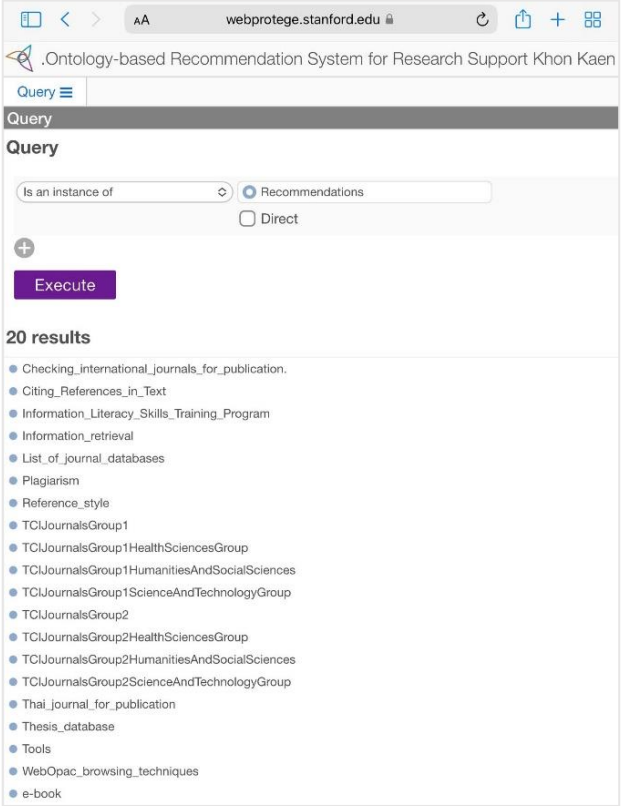

Fig. 13. Recommendation display for researchers based on rule design.

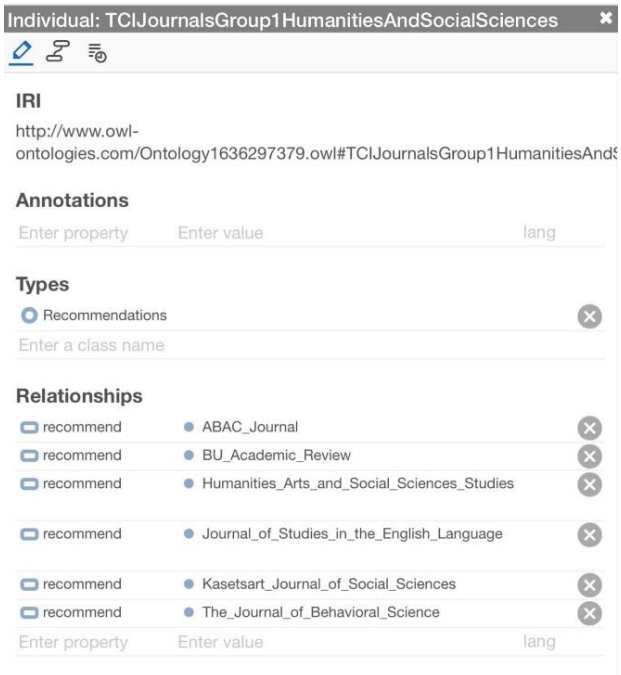

Fig. 14. An example of a recommendation of a list of TCI journals, Group 1, humanities and social sciences for publication of results.

2) *Display of user-defined conditional recommendations*

It displays instructions based on user-defined conditions. This is a preview of the data in each class according to the user's instructions. The "Research Support Class" has four main classes, including; "Information Literacy Class," "Information Class," "Informatics for Reference and Research Class," and "Research Tools Class," as shown in Fig. 15. There are steps to create conditions for filtering information as follows.

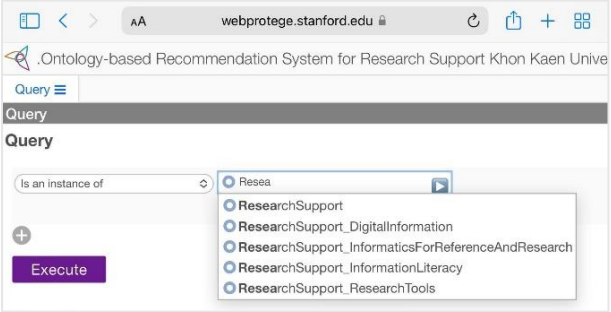

Fig. 15. List of domain base classes "Research Support".

First data screening from the main class "Digital Information Class." The system will display 184 snippets of all data within the class, as shown in Fig. 16.

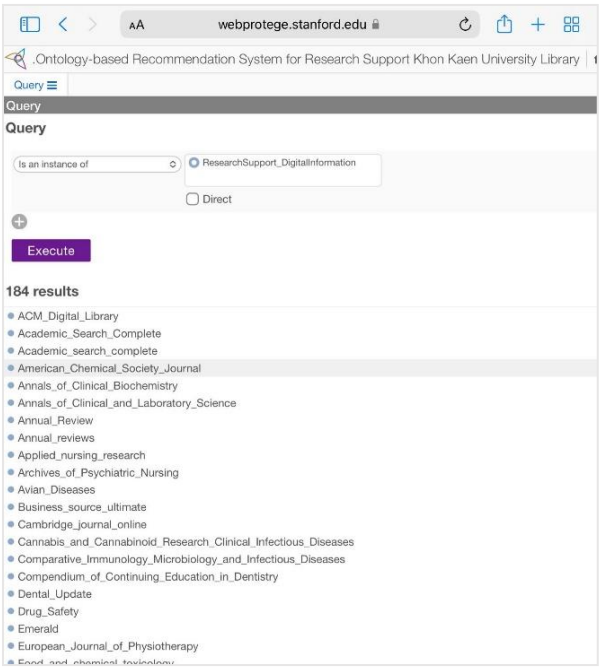

Fig. 16. Examples of data screening results "Digital Information Class".

The second screening of data sets conditions for the system to narrow the recommendations. Press the plus sign, select Is an instance of, and type the base class name to execute the process as "Digital Information Classes," then the system will display a list of related subclasses. There are three sub-classes to choose from: "Electronic Thesis Database Class," "E-Journal Class," and "E-Book Class." Select "digital information_electronic journal" to be used as an example for display, as shown in Fig. 17. The sample of the electronic journal class data screening is shown in Fig. 18.

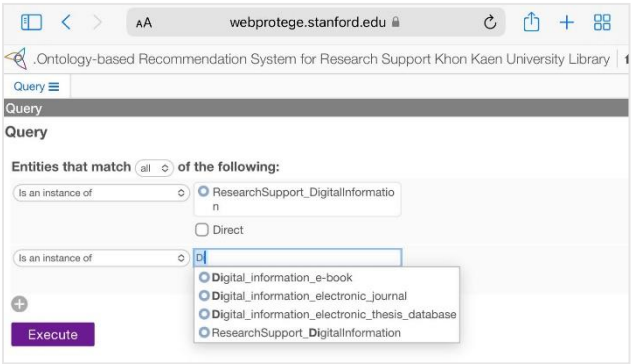

Fig. 17. An example of the result showing the options of "Digital Information Core Class".

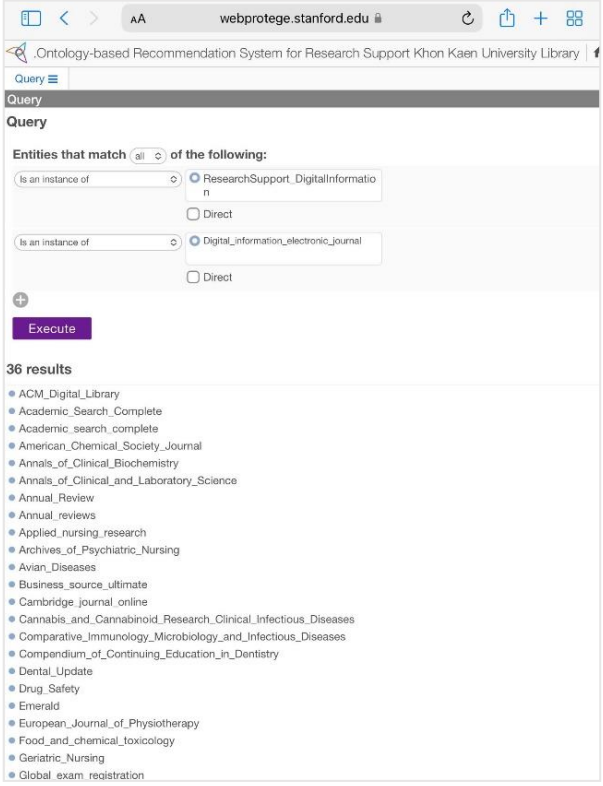

Fig. 18. An example of data screening results "Electronic Journal Class".

The third screening of data sets conditions for the system to narrow down the recommendations. For the system to process, press the plus sign, select Is an instance of, and type the name "e-journal class." The system will then display a list of the associated subclasses. There are three sub-classes to choose from: "Humanities and Social Sciences Group," "Health Sciences Group," and "Science and Technology Group." Select "Electronic Journals_Humanities and Social Sciences Group" to use as an example to display the results, as shown in Fig. 19.

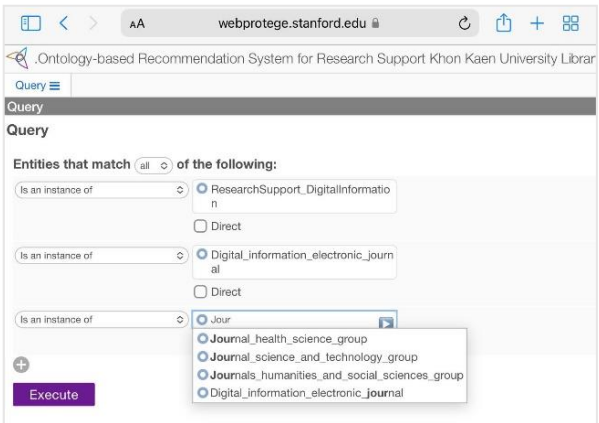

Fig. 19. An example of the result showing the options of "Electronic Journal Class".

For the results of the introduction of the list of electronic journals in the humanities and social sciences group that have passed the conditional screening, there are a total of 10 items including; Academic_search_complete, Annual_reviews, Business_source_ultimate, Cambridge_journal_online, Emerald, Global_exam_registration, Nikkei_asia, Oxford_e-journals, Sciencedirect, and Web_of_scien, as shown in Fig. 20.

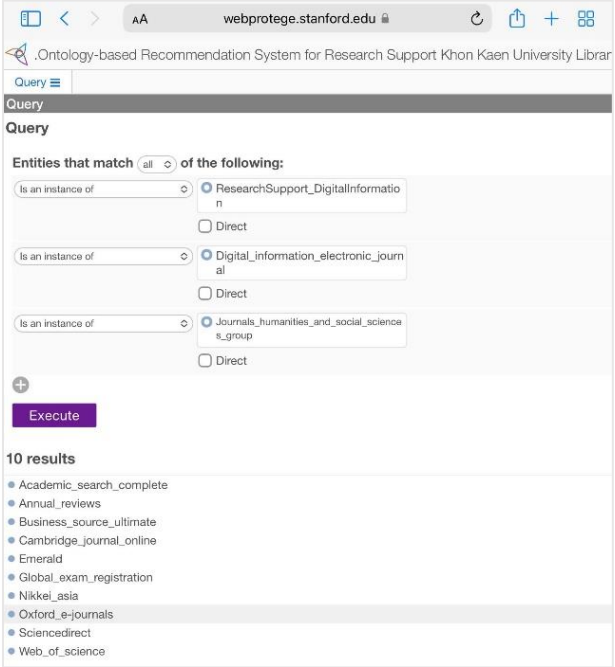

Fig. 20. An example of a recommendation screened with a conditional list of electronic journals in the humanities and social sciences group.

C. Performance Assessment Using Information Retrieval (IR)

1) Evaluation

The ontology is not an artifact in the narrow aspect but is expressed by ontology documents, which are artifacts. Whenever one speaks about ontologies as artifacts, they mean relevant ontology documents. Evaluation methods are descriptions of procedures that assess a specific quality of an ontology. Since the evaluation cannot assess the ontology directly (as it is not an artifact), the direct evaluation method is always on ontology documents. Therefore, only indirectly, it is possible for an evaluation method to assess ontology rules.

The established ontology rules assessment tests the ontology's affinity structure that has evolved following the ontology development process. This is a way to verify that the ontology is valid and meets the development objectives. Vrandecic [11] has presented a method for testing: a semantic query (SPARQL Query) based on data structures in a Triple form. Furthermore, by querying for answers to 20 essential questions, the baseline questions have been expanded upon by Smit, B. *et al.* [12].

a) Method of system evaluation

It is well-known that measuring or evaluating system performance and accuracy is very important after the Information Retrieval (IR) technique was designed. According to modern information retrieval [13], two important measures of retrieval system performance are a) system efficiency and b) system effectiveness. In this study, the efficacy is measured by Precision and Recall. Precision and recall are well-known as the primary methodology for evaluating recall systems [14]. In addition to precision and recall, F-measure is also used to measure system performance, which is suitable for testing accuracy.

$$\text{Precision} = \frac{\text{number of retrieved that are relevant}}{\text{total number of retrieved documents}} \quad (1)$$

$$\text{Recall} = \frac{\text{number of retrieved that are relevant}}{\text{total number relevant in the collection}} \quad (2)$$

b) Selecting text for a query

To show the effectiveness of the ontology rules designed and created, choosing a search question is therefore very important. In this study, twenty search questions were randomly selected to determine the effectiveness of the ontology rules. An average of 20 questions was used to measure the precision and recall performance of the system. The total number of documents used was 800 as shown in Table I.

TABLE I: QUERY SELECTION

No of Query	Queries	Number of documents which are:	
		Relevant	Irrelevant
1	Is writing a bibliography based on the graduate school format?	150	650
2	Ask for the correct way to write a bibliography.	40	760
3	KKU adheres to which reference format?	45	755
4	What format is used for journal citations?	20	780
5	What is a journal database?	90	710
6	What is the thesis database?	30	770
7	What is an e-book database?	45	755
8	I would like to know the list of journals for publishing academic results by subject groups in TCI Groups 1and .2	40	760
9	What is the Turnitin plagiarism verification process?	40	760
10	Turnitin should be able to review individual chapters or combine files.	15	785
11	How to view a journal's Impact Factor?	40	760
12	How to find journal ranking?	55	745
13	How to find information in Web OPAC to meet your needs?	35	765
14	I would like to know, how to check the index (Impact factor) of foreign journals?	75	725
15	I would like to know how to check the ranking of foreign journals.	50	750
16	I would like to know how to check and avoid plagiarism of academic works.	70	730
17	I want to attend Zotero training course	80	720
18	I want to know a list of tools to help manage document citations?	85	715
19	Ask for a list of tools to help you check English grammar.	95	705
20	Request a free tool to check academic plagiarism.	100	700

From Table II, the average of precision and recall values obtained in this study were 92.73% and 90.74%, respectively. It displays the percentage of Precision and Recall.

TABLE II: EXPERIMENTATION RESULT

No of Query	Queries	TRC	TR	RR	P (%)	R (%)
1	Is writing a bibliography based on the graduate school format?	12	14	12	89.55	97.99
2	Ask for the correct way to write a bibliography.	12	14	10	89.86	81.43
3	KKU adheres to which reference format?	12	14	11	90.17	89.32
4	What format is used for journal citations?	12	14	12	90.48	97.17
5	What is a journal database?	12	14	11	90.78	88.82
6	What is the thesis database?	12	14	11	91.09	88.57
7	What is an e-book database?	12	14	12	91.40	96.36
8	I would like to know the list of journals for publishing academic results by subject groups in TCI Groups 1and .2	12	14	10	91.71	80.08
9	What is the Turnitin plagiarism verification process?	13	14	11	92.02	87.84
10	Turnitin should be able to review individual chapters or combine files.	13	14	12	92.33	95.56
11	How to view a journal's Impact Factor?	13	14	12	92.64	95.30
12	How to find journal ranking?	13	14	12	92.95	95.04
13	How to find information in Web OPAC to meet your needs?	13	14	12	93.26	97.52
14	I would like to know, how to check the index (Impact factor) of foreign journals?	15	15	14	100.00	93.33
15	I would like to know how to check the ranking of foreign journals.	10	12	10	83.33	100.00
16	I would like to know how to check and avoid plagiarism of academic works.	12	13	12	93.68	98.53
17	I want to attend Zotero training course	13	14	11	95.27	85.00
18	I want to know a list of tools to help manage document citations?	14	14	11	96.72	77.76
19	Ask for a list of tools to help you check English grammar.	14	15	11	98.06	77.28
20	Request a free tool to check academic plagiarism.	15	15	14	99.30	91.95
Average					92.73	90.74

Note: TRC=Total Relevant In the collections, TR = Total Retrieved, RR = Relevant Retrieved, P = Precision, R = Recall

2) Performance measurement with F-measure

F-measure allows the system to increase recall by reducing accuracy and sometimes vice versa. There is a precise recall exchange (e.g., recalls can be increased simply by fetching relevant documents, but the accuracy will be decreased). F-measure combines precision and recall using harmonic mean. The F-measure is higher when both Precision and Recall are high. The formula is as following:

$$F - measure = \frac{2PR}{(P+R)} \quad (3)$$

Therefore, the F-measure performance from the above average and recall can be calculated by

$$F = \frac{2(0.9273)(0.9074)}{0.9273 + 0.9074}$$

$$F = \frac{1.6829}{1.8347}$$

$$F = 0.9172$$

The F-measure result obtained from this study is 0.9172. This indicates that the system precision is 91.72%. The F–measure assumes a value in the [0,1] range when no relevant documents are retrieved, 0 and 1 when all retrieved documents are relevant, and all relevant documents have been extracted. Therefore, it is possible to perform a research knowledge search for service advisories at the Khon Kaen University Library from the system using ontology rules.

This representation provides a consistent model for gathering and processing a consulting ontology for research support services of the Khon Kaen University Library. In this study, the ontology rules are our recommender context model. After building this ontology, the next step is to apply some filtering techniques to deliver the recommendation object corresponding to its recommender context to users. We propose to filter recommendation objects by applying a set of business rules, indicating which recommendation object is to be recommended in what context. These filtering rules will be used as a recommendation technique because they synthesize the domain knowledge and the constraints that the system must satisfy. Indeed, the business rules are transformed into SWRL sequences. The recommendation system uses the implemented rules to analyze the raw data inside the database and the knowledge in ontology to obtain valuable and particular knowledge. The recommendation systems consist of a stand-alone system that can take several steps to complete the tasks.

III. Conclusion

This article presents the application of a semantic web concept for developing a body of knowledge for providing advice on research services at the Khon Kaen University Library by developing ontology prototypes with semantic rules for integration into systems or software for retrieving data from semantic knowledge bases. The main issue in developing ontology focuses on the body of knowledge for providing advice on research services at the Khon Kaen University Library. The results of the research present semantic rules for incorporating additional information together with the application of ontology which can create a complete body of knowledge. The ontology rules test uses information retrieval methods with a semantic query technique using the SPARQL Query language. This is a method used to test data that has been structured according to the ontology. The testing is performed through a query based on the relationship of the data structure. The search will be based on the basic questions that have been set. This is because the fundamental question is one of the important tools in determining the scope of an ontology, to what extent an ontology must be structured to cover information, and to what questions the ontology has to answer. Nevertheless, the limitation of the questioning is that the person asking the question must be an expert in that domain. In this research, the main question is based on the concept of [12] and extended to cover the information in the ontology to be used in testing. The testing results showed that data was described as an ontology-based data structure and, through inference and semantic rules, could answer fundamental questions correctly according to the model ontology structure. Furthermore, these developed semantic rules can be used as a recommendation system or semantic search application knowledge structure. In future research, this model of ontology and semantic rules will be used in conjunction with research to develop a recommendation system for research support services based on the complete Khon Kaen University Library's semantic knowledge base.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Yuwapa Ruger and Wirapong Chansanam conducted the research; Malee Kabmala collected and analyzed the data; Wirapong Chansanam and Malee Kabmala gave guidance on the conceptual research; all authors had approved.

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