Some Techniques for Intelligent Searching on Ontology-based Knowledge Domain in e-Learning

Nhon V. Do[1,*], Hien D. Nguyen[2,3,*,✉][a] and Long N. Hoang[1]

[1]*Hong Bang International University, Ho Chi Minh city, Vietnam*

[2]*Faculty of Computer Science, University of Information Technology, Ho Chi Minh City, Vietnam*

[3]*Vietnam National University, Ho Chi Minh City, Vietnam*

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Abstract: E-learning is the modern way to learn by using electronic media and information and communication technologies in education. Ontology is a useful method to organize knowledge bases for intelligent educational systems. In this paper, a method for intelligent searching on ontology-based knowledge domain in e-learning is presented. This method includes an ontology representing educational knowledge domains, called Search-Onto. The foundation of this ontology is concepts, relations between concepts, operators, and rules combining the structures of problems and their solving methods. Beside the ontology organizing the knowledge base, the proposed method also studies some techniques for intelligent searching, such as searching for the knowledge content, searching on the knowledge classification, and searching the related knowledge. The method for intelligent searching based on a knowledge base has been applied to construct a search engine for the knowledge of high-school mathematics. This engine can do searching works and retrieve required information in mathematics for high-school students to support their learning.

1 INTRODUCTION

Nowadays e-learning is the way in which learning is imparted to students by using electronic media and information and communication technologies in education (Zavyalova, 2020). For the effectiveness of e-learning, search engines are necessary tools for finding some information which are required for the learning process (Veletsianos, 2010). By using this system, learners can retrieve the knowledge of a course to study by themselves.

Intelligent search utilizes computers to gather insight by reading and interpreting all file types like a human being (Bast et al., 2016, Sajja and Akerkar, 2012). Intelligent search in e-learning is a search engine on learning resources. This engine is designed based on a knowledge base organizing the knowledge domain of courses. It is able to retrieve the knowledge content matching the meaning of an inputted query, and anticipate the user's needs via automatic suggesting the related knowledge to current searching results.

The requirements of an intelligent searching system in education are established based on criteria of an intelligent educational system (Nguyen et al., 2020b, Hatzilygeroudis and Prentzas, 2006):

- The system has a knowledge base representing the knowledge of courses completely.
- The system can search information on learning resources to support the learning. It can analyze the meaning of a query and get results, which are suitable for that meaning, from its knowledge base.
- The system can predict the user's needs and propose the knowledge related to current searching results.

Ontology is a useful method to organize knowledge bases for intelligent educational systems (Noy et al., 2013). Ontology COKB (Computational Objects Knowledge Base) was used to represent the

[a] https://orcid.org/0000-0002-8527-0602

✉ Corresponding author

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knowledge domains about discrete mathematics (Nguyen and Do, 2017) and graph theory (Do et al., 2018). Rela-model is an ontology representing the knowledge of relations. This model and its extension was also applied to represent the knowledge of courses about Algorithms (Le et al., 2019b). One of properties of an ontology is the communication between people and other heterogeneous distributed application systems (Giri, 2011); thus, ontology is also effective to apply for represent the knowledge base of an intelligent search engine (Grosan and Abraham, 2011), especially the searching systems in e-learning.

In this paper, an ontology representing an educational knowledge domain is presented. This ontology, called Search-Onto, can represent all components of a course's intellectual content. The structure of this ontology is constructed based on the knowledge of relations and operators (Nguyen et al., 2020a, Nguyen et al., 2018). Its foundation includes concepts, relations between concepts, operators, and rules of the knowledge domain. Some problems, which are common exercises of this course, and their solving methods also can be represented by this ontology. Search-Onto is a useful ontology to build intelligent search engines. Some techniques for intelligent searching based on this ontology have been studied: searching for the knowledge content, searching on the knowledge classification, and searching the related knowledge. Besides, the ontology Search-Onto and searching techniques have been applied to build an intelligent search engine for the knowledge of high-school mathematics. This system organizes this knowledge domain completely. It can do intelligent search works and retrieve required information for students to support their learning.

2 RELATED WORK

There are many methods for building search engines which are semantic searching systems on text and knowledge bases (Bast et al., 2016). However, those systems have not yet equipped a reality knowledge base with some techniques for intelligent search. For supporting e-learning, the search engine is an important function to help learners being able to retrieve necessary information for their studying.

Docxonomy (2020) is a search engine by extracting the meaning from files automatically. It gathers knowledge, understanding, and context by using artificial intelligence to read and interpret data just as a human being would. However, this system has not a knowledge base to store the knowledge domain, and it is too general to apply in a course of learning.

Yext's Intelligent Search Tracker allows users to track up to keywords based on the data stored in the Yext Knowledge Manager (Yext, 2020). This tool helps to understand how a business performs in intelligent search. The knowledge manager of Yext contains the information of businesses. It does not have a reality knowledge. Therefore, this searching system is only effective for some simple works in e-commerce.

In (Le et al., 2019a), authors described a method to build a data advising system, which is an intelligent recommender system for Data Science. It can search courses, events, books, and connect users with employers/businesses in Data Science (DamSanX, 2020). Nonetheless, this system does not have a knowledge base to support some intelligent search based on analyzing the query's meaning. Besides, it also does not tend to users who are students finding the knowledge of their course; thus, it cannot support the learning of students.

The framework of Multimodal Attention-based Neural Network is applied to find similar exercises in online education systems (Liu et al., 2018). It is worked by learning a unified semantic representation from the large data. However, those systems did not search the content of knowledge about a course with the query as natural language.

3 ONTOLOGY FOR SEARCHING KNOWLEDGE DOMAIN

Fig. 1 shows an architecture of an intelligent search engine based on the knowledge base. The knowledge base of this system is extracted from the knowledge domain collected in the real-world. The user will input a query to the system. Firstly, the system analyzes the semantic of query and classifies it to a searching problem suitably. If the system cannot understand the query, it will generate some questions to determine the exactly searching content. Secondly, the search engine is worked to do some intelligent searching techniques based on the organized knowledge base. Finally, the system outputs results and their related knowledge to the user.

In practical, the knowledge domain of a course has many components. Thus, the knowledge model for this domain needs to be performed those components. One of ontology methods for representing the knowledge base of an intelligent search system is

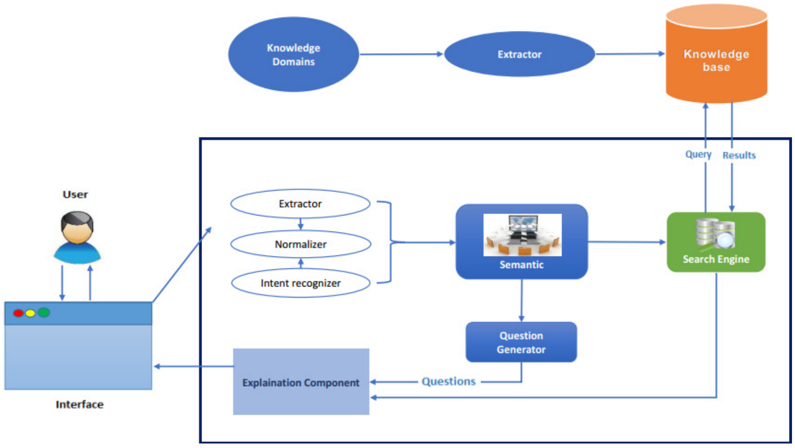

Figure 1: The architecture of an intelligent search engine based on knowledge base.

constructed based on the structure of the knowledge model of relations combining some other intellectual components. In this study, this ontology is an integration between the Rela-Ops model (Nguyen et al., 2018) and structures of problems with their methods for solving them (Do et al., 2017).

3.1 Knowledge Model of Relations and Operators

Rela-Ops model is an ontology representing the knowledge of relations and operations (Nguyen et al., 2020a). This model is useful to apply in the practical knowledge domains, which require the combination between those kinds of knowledge when solving problems on them (Nguyen et al., 2020b).

Definition 3.1 (Nguyen et al., 2018): Rela-Ops model is a tube including 5 components:

(C, R, Ops, Rules)

In which, **C** is a set of concepts, each concept is a class of objects. **R** is a set of other relations between concepts, objects and objects' attributes. Those relations are some special relations, such as "is-a" and "has-a", and other binary relations. **Ops** is a set consisting of operators on **C**. Set **Rules** represents deductive rules of the knowledge domain. The rules represent statements, theorems, principles, formulas, and so forth. The detail of structures of each Rela-model's component has been presented in (Nguyen et al., 2020a).

3.2 Ontology for Searching Knowledge Domain

On a knowledge domain for searching, besides the basic knowledge of a course, it also has the knowledge of exercises and methods for solving them (Do et al., 2017). Those knowledge is useful for learners when they want to search its application for solving some common exercises in that course.

Ontology for searching knowledge domain of a course is the combination between ontology Rela-Ops model and the knowledge of common exercises and their solving methods.

Definition 3.2: Ontology for searching knowledge domain, called *Search-Onto*, is a tube:

(C, R, Ops, Rules) + (Problems, Methods)

In which, **(C, R, Ops, Rules)** is an ontology as Rela-Ops model; however, each component has been improved its structure representing its knowledge more exactly, especially the knowledge for the interpretation of its meaning.

Problems is a set of problems/exercises of a course, this component collects all basic exercises which are characteristics of a course. **Methods** is a set of methods for solving problems.

3.2.1 Problems–set of Problems/Exercises

Problems-set is a set of problems/exercises in a course. Each problem is a tube of five elements:

(Name, Category, Content, Hypo, Goal)

- *Name*: it is a string used to identify the problem. Some problems can be referred to by different names, so this element will only take the most commonly used keyphrases to identify the problem as its value.
- *Category*: the category of the problem.
- *Content*: describe the problem as HTML text.
- *Hypo*: The specification of the problem's hypothesis.
- *Goal*: The specification of the problem's goals.

3.2.2 Methods–set of Methods for Solving Problems

Methods-set is a set of methods for solving problems. Each method is bound to solve a specific problem. It can be represented as a tube of four elements:

(Name, Content, Problem, Illustration)

- *Name:* it is a string used to identify the method. Some methods can be referred to by different names, so this element will only take the most commonly used keyphrases to identify the problem as its value.
- *Problem*: this element represents the problem which this method is bound to solve.
- *Content*: it is a HTML text describing the content of this method.
- *Illustration*: it is a set of illustrations on some practical problems for this method.

4 SOME TECHNIQUES FOR INTELLIGENT SEARCHING ON ONTOLOGY

There are many requirements for searching on the knowledge domain. A system of intelligent searching has the ability to search the knowledge as each kind of it, such as searching for concepts, relations of knowledge, or related knowledge to current results. This section presents some techniques to solve some problems for intelligent searching on the knowledge domain based on ontology.

(1) Searching for the content of knowledge: this searching returns the results based on the meaning of the user's query.

(2) Searching on the classification of a knowledge domain: it returns the results of searching based on types of knowledge. Some categories of educational knowledge are: concepts, relations, rules, kind of problems as well as methods for solving them.

(3) Searching for related knowledge: this kind of searching returns some knowledge which has relations with the current searching automatically. The related knowledge helps users to catch required information.

4.1 Searching for the Knowledge Content

The searching of the knowledge content returns a set of knowledge based on the meaning of an inputted query. The system determines the meaning of this query from its extracted keywords. This searching is worked through the determination of similarly meaning between keywords of the query and stored knowledge. There are two problems for designing this kind of searching.

Definition 4.1 (): Let K be a knowledge domain as ontology Search-Onto or a component of ontology Search-Onto, and an object o.

Define: *Com*(K) is a set of components of K.

key(o) is a set of keywords of o with $o \in k$ and $k \in Com$(K).

Problem 4.1: Let $\mathcal{K}$ be an ontology of knowledge domain as Search-Onto, and $o \in Com$(K) where K = $\mathcal{K}$ or K $\in Com(\mathcal{K})$, a keyword w. Determine a keyword $w' \in key(o)$ which is the word has the most similar meaning with keyword w.

Denote: $w' := Mean(w, key(ob))$

Problem 4.2: Let $\mathcal{K}$ be a knowledge domain as ontology Search-Onto, and a query q. Determine a set of knowledge which are appropriate to the meaning of query q.

For problem 4.1, the measure for similarly meaning is computed by the tube ($tf(v, o)$, $idf(v, K)$), where $tf(v, o)$ is the term frequency representing the frequency of a keyword v in an object o, and $idf(v, K)$ is the inverse document frequency representing the specificity of keyword v in knowledge K. The formulas of ($tf(v, o)$, $idf(v, K)$) are established as follows (Le et al., 2019b):

$$tf(v,o) := c + (1-c)\frac{n_{v,o}}{max\{n_{v',o} | v' \in key(o)\}} \quad (1)$$

where, $n_{v,o}$ is the number of occurrences of the keyword v in the object o,

$c \in [0, 1]$ is a parameter which is the minimum value for every keywords.

$$idf(v,K) := log\left(\frac{\text{card}\left(\cup_{o \in Com(K)} keyw(o)\right)}{1 + \text{card}(\{o \in Com(K) | v \in key(o)\})}\right) \quad (2)$$

Let $\mathcal{K}$ be a knowledge domain as ontology Search-Onto, and a query q. This algorithm determines a set of knowledge which are appropriate to the meaning of the query q.

Input: The knowledge domain $\mathcal{K}$ as Search-Onto.
A query q.

Output: Set of knowledge being appropriate the meaning of the query q.

Algorithm 3.1:

Step 0: *Initialize*

W := set of extracted keywords from query q.

Knowledge := {} // set of query results.

If (there exist a keyword about type of knowledge in W) **then**

Search := set of components of $\mathcal{K}$ related to the type of knowledge.

Else

Search := *Com*($\mathcal{K}$)

Step 1:

Extract keywords which are closest meaning with words in *W* of a query sentence.

$$Keywords := \bigcup_{o \in Search} key(o) \quad (3)$$

Use problem 4.1 to compare per word $w \in W$ with words in *Keywords* by their meaning and select the word in *Keywords* which has the most appropriate meaning with *w*.

$$MainWords := \bigcup_{w \in W} Mean(w, Keywords) \quad (4)$$

We have, $MainWords \subseteq KeyWords$

Step 2:

Retrieve knowledge from components in *Search* based on keywords in *MainWords.*

Update *Knowledge*.

Step 3:

Unification of facts in the knowledge model and the comparison the meaning of them by using problem 4.1.

Update *Knowledge*.

Step 4: Return results in *Knowledge*.

4.2 Searching on the Classification of a Knowledge Domain

The knowledge domain has many knowledge components, such as concepts, relations, and theorems, properties of concepts, objects. Especially, in the educational knowledge domain, there is the knowledge of common exercises of that course and methods for solving them. The searching on the classification of a knowledge domain helps users to find necessary information which they need. This searching is worked based on determining the type of searched knowledge in a query. For designing this kind of searching, the algorithm has two stages as follows.

Stage 1: *Determine the category of an inputted query*.

The determination is solved by using the corpus of the knowledge domain. For example, if the query is "what is a triangle", then the category of this query is the concept. This corpus is collected from the knowledge source. Through that corpus, the system can detect the type of searched knowledge. The process for solving this problem consists of three main parts of natural language processing: word segmentation, chunking and selecting candidates (Pham et al., 2020).

Word segmentation is a task to divide a string of natural language into its component words. Chunking is a process to extract phrases from unstructured sentences. The core idea of this step is the choosing of the phrases, which have chunking tags: NP (Noun phrase), VP (Verb phrase) and QP (Question phrase), as candidate keywords. While NP and QP contain the key information of queries, QP determines the type of queries for query classification that will be presented in subsequent sections. Candidates selection is the final step of the query processing. Based on the structure ontology Search-Onto representing the knowledge K, the heuristic approach is used for selecting keywords. Using selecting keywords from the query, the matching of them and each component of ontology Search-Onto determines the corresponding category for the knowledge in the input query.

Stage 2: *Matching the searching knowledge and the knowledge in its category*.

From the types determined at Stage 1, the search engine retrieves the knowledge from components of ontology Search-Onto. It uses Algorithm 3.1 to find the content in the corresponding components matching the information extracted from keywords of the inputted query.

4.3 Searching for Related Knowledge

The related knowledge is a set of knowledge related to the current searching knowledge. That related knowledge help users understanding more the content of their searching. In this paper, the related knowledge is a set of knowledge which have relations with the current searching results in the ontology Search-Onto representing the knowledge domain.

Let $\mathcal{K}$ be a knowledge domain as ontology Search-Onto, a query *q*, and the results of query *q*. This algorithm determines a set of knowledge related to the knowledge results of query *q*.

Input: The knowledge domain $\mathcal{K}$ as Search-Onto. A query *q*.

Output: Set of knowledge being appropriate the meaning of the query *q*.

Algorithm 3.2:

Step 1:

Knowledge := set of knowledge results for the query q. It is determined by using algorithm 3.1 or algorithm 3.2,

Step 2:

For each o in *Knowledge* **do**

Determine the set of knowledge related to o

$$\text{Related}(o) := \{o' \mid \exists\, r \in \mathcal{K}.\mathbf{R},\, r(o, o')\}; \quad (5)$$

Step 3:

Determine the set of knowledge related to the *Knowledge*-set:

$$\text{Relate}(Knowledge) := \bigcup_{o \in Knowledge} \text{Related}(o) \quad (6)$$

Classify the knowledge in Relate(*Knowledge*) based on types of knowledge of ontology Search-Onto model.

Step 4: Show results in Relate(*Knowledge*) by that classification.

5 INTELLIGENT SEARCH ENGINE FOR THE KNOWLEDGE OF HIGHSCHOOL MATHEMATICS

Mathematics is an important course for high school students. The demand of students for supporting to learn this course is very high, especially when they want to review for preparing their final exams. Based on the ontology Search-Onto represented in section 2 and the searching problems in section 4, an intelligent search engine for the knowledge of high-school mathematics in Vietnam has been constructed. This system can support the studying of students via the supplying of required contents of the course based on the user's searching. The system has a knowledge base which is extracted from this knowledge domain collected in (Vietnam Ministry of Education and Training, 2017).

5.1 Design the Knowledge Base

The high-school pupils are the main kind of people using our system. They will use our program to support their studying. Knowledge base, which stores the knowledge domain about high-school mathematics, is organized by the ontology Search-Onto as Section 3.2.

(C, R, Ops, Rules) + (Problems, Methods)

There are some examples for geometric knowledge represented in the searching system.

a) C–set of concepts of geometric knowledge

The set C consists of concepts such as "Point", "Segment", "Line", "Triangle", "Quadrilateral", "Plane", "Pyramid", etc.

b) R–set of relations between concepts

The set R includes two kinds of relations:

- The relations "is-a" between concepts.
- Other binary relations, such as:

• Relations *intersect*: relations about intersection between two lines, two planes, a line and a plane, etc.

• Relations *parallel* (//): relations about parallel between two lines, two planes, a line and a plane, etc.

• Relations *perpendicular* ($\perp$): relations about perpendicular between two lines, two planes, a line and a plane, etc.

c) Ops–set of operators

In knowledge about plane geometry, some operators are represented:

Ops := {*Projection*, *Symmetric*}

• Projection of a point on a line or a plane, projection of a line on a plane.

• Symmetrical point of a point through a line.

d) Rules–set of inference rules

Almost all properties, clauses, theorems in high-school geometry can be represented by structures of rules in Search-Onto. Some particular rules are:

r_1: {a: segment, b: segment, c: segment},
{a // b, c $\perp$ a} $\rightarrow$ {c $\perp$ b}

r_2: {A: point, B: point, C: point},
{BC = AC}$\rightarrow${ABC is an isosceles triangle at C}.

r_3: {A: point, B: point, C: point},
{AB $\perp$ BC}$\rightarrow${ angle ABC = 90°}.

e) Problems–set of Sample Problems:

There are some common problems about Right Triangle, Rectangle, Circle, etc., such as:

• Solving a right triangle.

• The problem about determining relations between diameter and chord of circle.

• Problems about the properties of a pyramid.

f) Methods–set of methods for solving some problems:

There are some methods for solving problems, such as:

• Method for solving a right triangle.

• Method for solving an isosceles triangle.

• Method for solving the problem about determining relations between diameter and chord of circle.

• Method for solving the problem about properties of an inscribe quadrilateral.

Table 1 shows some topics for algebraic knowledge at high-school in this system:

Table 1: Some topics for algebraic knowledge at high-school.

Order	Group of topics
1	*"set"*, *"functions"*, *"equations"*, *"inequalities"*, *"graph"*.
2	*"trigonometric equations"*, *"trigonometric functions"*, *"lines"*, *"plane"*, *"derivative"*, *"limit"*, *"vector"*.
3	*"differentiation"*, *"logarithm"*, *"exponential"*, *"analyzing functions"*.

Those knowledge of ontology Search-Onto are organized by the system of structured text files:

- Files store names of concepts and their structures.
- Files store the specification of relations and operators between concepts.
- A file stores inference rules.
- Files store sample problems.
- Files store the specification of methods for solving problems.

Example 5.1: For each concept, the corresponding file has the file name <concept_name>.txt. That file specifies the structure of the concept. The file's structure as follows:

```
begin_concept: <concept name> [based objects]
    specification of based objects
  begin_variables
      <attribute name> : <attribute type>;
      ...
  end_variables
  begin_ relations
    begin_relation
      specification of a relation
    end_relation
    ...
  end_ relations
  begin_rules
    begin_rule
        kind_rule = "<kind of rule>";
        hypothesis_part:
            {facts}
        goal_part:
            {facts}
    end_rule
    ...
  end_rules
end_concept
```

5.2 Testing and Experimental Results

The searching system for the knowledge of high-school mathematics has been tested by 97 students at two high-schools. There are 31 students studying at 10^{th}-grade, 29 students at 11^{th}-grade, and 37 students at 12^{th}-grade.

Each student inputs 03 queries for searching the knowledge of mathematics. The queries belong to: searching definitions of mathematics in the curriculum, searching properties and rules, searching kinds of exercises and searching the method for solving some kinds of exercises. The related knowledge has been shown automatically with the results of the searching. The results of the inputted queries have been double checked:

- If the student recognizes the results being suitable for them, they will check on the system.
- Besides, those results are noted. They will be evaluated by the lecturers in mathematics later.
- If the results are checked by students and lecturers, they will be correct.

The experimental results are shown in Table 2 and Fig. 2. In this table, some duplicate queries were omitted.

Table 2: Experimental results on tested queries.

Search content	Number of queries	Correct	Rate
Definitions in mathematics	101	81	80.2%
Properties, rules	62	42	67.7%
Kinds of exercises	59	43	72.8%
Solving methods	53	38	71.7%
Total	**275**	**204**	**74.2%**

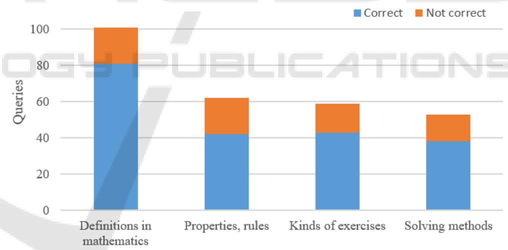

Figure 2: Compare the results between search contents.

Students usually search definitions of mathematics and their properties. They have a need to understand the knowledge more clearly. Concepts in mathematics are separate, the searching on each definition is more exactly than others. When searching for rules and properties, because there are many rules which have the same kinds and same objects, those queries do not return the correct results.

6 CONCLUSION AND FUTURE WORK

This article presents an ontology representing the knowledge base of an intelligent educational searching system, called Search-Onto. This ontology is built based on the knowledge model of relations and operators combining the structures of problems and their solving methods. Besides, some techniques for intelligent searching have been designed based on the knowledge base. Those kinds of searching are: Searching for the knowledge content, searching on the classification of knowledge and searching for related knowledge.

Ontology Search-Onto has been applied to represent the knowledge domain about high-school mathematics for an intelligent searching system on this domain. The built system can retrieve required information matching the meaning of an inputted query. The system can get some related knowledge to the search content. It is helpful to support high-school students in learning mathematics.

In the future, the studying of combining an intelligent search system and an architecture of chatbot (Nguyen et al., 2019) will build an intelligent chatbot for question-answering the knowledge of courses. This chatbot can interact and help users more naturally. Moreover, the intelligent search system in e-learning will be integrated to the intelligent problem solver in education (Nguyen et al., 2020a) and the intelligent supporting system for multiple choices training test (Mai et al., 2018). The integrated system will be a complete system to support the learning of students effectively.

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