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Intelligent System in Education: Requirements and Design Method

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Abstract: Intelligent systems in education have proven to be highly beneficial in supporting self-learning among students, particularly in remote learning scenarios. This study proposes the necessary requirements for an intelligent educational system that serves two primary functions: querying course knowledge and evaluating learner proficiency through multiple-choice testing. Furthermore, this study builds a solution to design the knowledge base, inference engine, and tracing system based on a knowledge model that integrates ontology and knowledge graph.

Keywords: Intelligent system, education, knowledge base, inference engine, multiple choice testing

1. Introduction

Intelligent systems are many applications in real-world [1, 2]. The architecture of an intelligent system consists of many components, in which, knowledge base and inference engine are most important components [3, 4]. The knowledge base stores the practical knowledge organized for this system, and the inference engine does for intelligent tasks, such as reasoning, searching on knowledge base [4, 5].

In the fourth Industrial Revolution, e-learning is developed to approach more learners [6, 7]. Intelligent systems in education are very useful to support the self-learning of students, especially in distance learning [7, 8]. It is the application of technology in educational settings to enhance the learning experience of students and to support teachers and administrators in managing and delivering education [9]. The goal of edtech is to create more effective and efficient learning environments that can better meet the needs of today's learners. There are many systems to help the studying. However, they have not yet been designed to be suitable for students completely.

The study in [10, 11] introduced methods for designing of searching system in high-school mathematics [10] and Data Structure and Algorithms course [11]. Those programs can do intellectual functions for searching/querying on knowledge content of courses. However, they did not support learners to review lesson contents.

Luong *et al.* [12] created a cloud computing-based support system for interactive education. They put standards for an interactive educational software. On the AWS cloud computing platform, the system architecture and development methodology were also being explained. Nevertheless, this solution did not supply the abilities for estimating the understanding measure of students. Thus, it was not effectively.

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Hocmai.vn is a platform for helping high-school pupils to review may subjects, especially mathematics knowledge through multiple choices test [13]. However, this program has not yet linked the content of questions to corresponding lessons in high-school mathematics, and it cannot give comments about results after the pupils' testing.

In this paper, the requirements of an intelligent educational system are proposed. These criteria are provided for two main purposes, including searching/querying on course content knowledge, and assessing learners' knowledge proficiency through multiple-choice exams. A solution to organize the knowledge base, inference engine, and tracing system based on a knowledge model that integrates ontology and knowledge graph was also provided in this work. The knowledge model, called *Rela-Graph ontology*, is an integrating between ontology for relational knowledge, Rela-model [14], and knowledge graph. Based on Rela-Graph ontology, the problems for inference engine and tracing system are studied and solved. Those problems consist of searching/querying on the knowledge domain, generating multiple choice tests automatically and evaluating the learners' knowledge level through tests.

The next section presents requirements for intelligent systems in education. These requirements for intelligent searching systems and knowledge evaluation systems through multiple choices test. Section 3 proposes a solution for designing an intelligent educational system meeting the described requirements. This solution includes an architecture for this system, methods for organizing the knowledge base, problems on inference engine and tracing system. The algorithms for solving those problems are also presented in this section. The last section concludes results and gives future works.

2. Requirements of Intelligent Systems in Education

2.1 General Requirements

Distance learning is a modern way for studying in the fourth industry of digital era. E-learning is an effective method to support students attending online course. E-learning needs an intelligent system to support learners to study more conveniently [15, 16]. Based on standards for an intelligent educational system, the requirements of an intelligent system in education are determined [17, 18]:

- Completely: The system must be equipped completely content of a course. It also supports the review of students fully, especially the searching on course contents and self-testing at a determined topic.
- Practicality: The system supplies content accurately. It is also convenient for users to learn everywhere and any time. The program can anticipate the user's needs and provide recommendations based on recent search results.
- Generally: The architecture and design methods of the system can be applied in many courses. The engineer can apply them with minor revisions for many courses.

2.2 Requirements for Intelligent Searching Systems in Education

Based on standards for an intelligent educational system, the requirements of an intelligent searching system in education are determined [10, 19]:

- To represent the knowledge of courses, the system has a comprehensive knowledge base.
- The system can search and query data from educational resources. It can interpret the meaning of a query and retrieve from its knowledge base results that are appropriate for that interpretation.
- The system can foresee the user's requirements and make recommendations based on current search results.

The system can assist with rapid searches inside those courses' content. The application allows users to search for content by lesson as well as by knowledge category. Additionally, the built-in system can suggest knowledge associated with the searched-for content. The system will provide knowledge relating to the user's search terms after returning the search results. From that, this kind of system must support students to search lessons of a course, search by classification of the knowledge domain, search the related knowledge and search by keywords. Table 1 and Fig. 1 describe content for each searching kind.

Table 1 - The content of each searching kind

Kinds	Content
Search lessons	• Users can search the lessons in the curriculum of this course
Search by classification the knowledge	• The kinds of knowledge: Concepts, Theorems, Properties, Kinds of exercises, solving methods. • Search the knowledge based on each these kinds
Search the related knowledge	• Each knowledge in the course is related to the others. • Show the related knowledge with the ones that are searching.
Search by keywords	• Search the knowledge by inputted keywords

Fig. 1 - Kinds of searching in intelligent searching system in education

2.3 Requirements for Knowledge Evaluation Systems through Multiple Choices Test

Multiple choice questions ask respondents to choose only the right responses from a set of options, which is a type of objective evaluation [20]. Multiple choice tests are a common way to assess student understanding in modern times [21]. Multiple choice questions come in a wide variety and can be divided into two categories: single-answer questions and multiple-answer questions [22]. The intelligent supporting system for multiple choices test training has to have the followed functions:

- Automatic test generation: The system must provide a test that satisfies the user's requirements based on those requirements. These specifications relate to the test's content, difficulty level, and quantity of questions.
- Determining a user's level of knowledge: Based on test results, the system may determine a user's knowledge of each subject.
- Evaluating the development of a user: Through completed tests, the system tracks a user's growth at each topic.

3. Design Components of Intelligent Systems in Education

3.1 The Architecture of an Intelligent System in Education

Figure 2 shows the construction of an intelligent educational system. The system has three main functions: searching or querying the knowledge of a course and evaluating the learners' knowledge through multiple choices test. The knowledge base stores the intellectual domain of the corresponding course. It is organized by suitable knowledge models. The inference engine is a component to support intellectual searching on the domain [4] and generating multiple choice tests by learners' demanding. The tracing system helps to follow the learning process of students and evaluate their knowledge level [23].

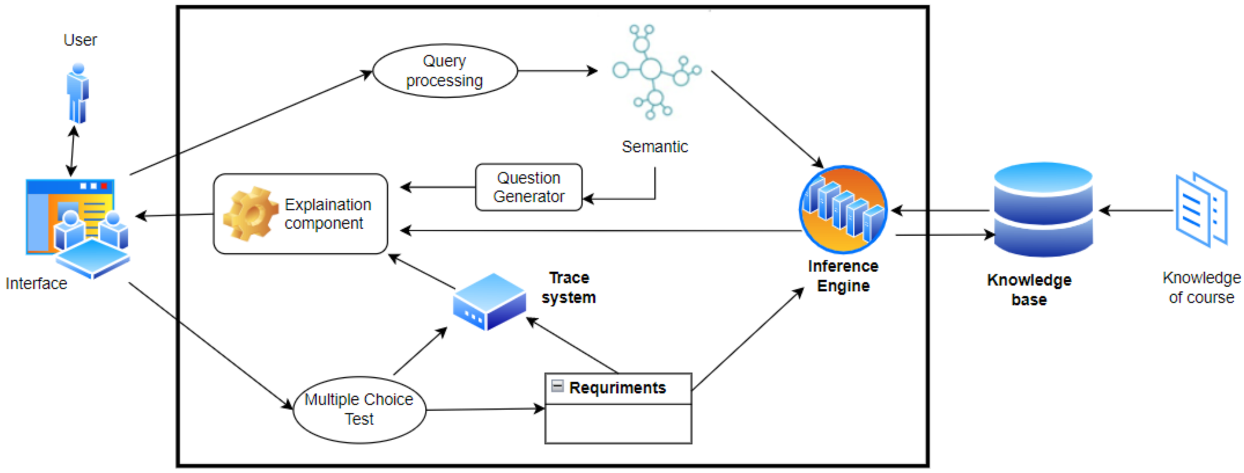

Fig. 2 - The architecture of an intelligent educational system

3.2 Components of the System

3.2.1 Knowledge Base

The knowledge base plays as a heart of the intelligent system in education. This component stores the knowledge of a course. It is the foundation for the system to do their actions, such as searching, reasoning and knowledge evaluating. This paper proposes an integration model of ontology Rela-model [14, 24] and knowledge graph for representing this knowledge base.

Definition 3.1: The integration model of ontology Rela-model and knowledge graph, called *Rela-Graph ontology*, consists of followed elements:

$$\mathrm{K} = \mathbf{(C, R, Rules)} \oplus \mathbf{G_{KG}}$$

In which, **(C, R, Rules)** is ontology Rela-model, which were presented in [14, 24], where, **C, R** and **Rules** are sets of concepts, relations between them and inference rules, resp.

$\mathbf{G_{KG}}$**:** = (V, E) is a two-layer knowledge graph, which performs the intellectual content in Rela model [19]. V is a set of vertices expressing the knowledge of concepts, rules, and the relations between knowledge attributes - according to the structure of knowledge graph.

Each vertex in V of the graph $\mathbf{G_{KG}}$ is classified into two kinds: **(Knowledge, Rules)** in which:

- **Knowledge** vertices: store contents of the course as natural language. That information will be shown for users when results are extracted.
- **Rules** vertices: include rules with relations, functions and operators related to inference rules of the knowledge domain.

E is a set of edges of this graph representing relations between vertices in **V**. There are two kind of edges in E:

$$E = \mathbf{E_{attrs}} \cup \mathbf{E_{objs}}$$

$\mathbf{E_{attrs}}$ is the set of edges representing relations between attributes in an object. Those attributes and their relations are the foundation of the corresponding object. $\mathbf{E_{objs}}$ is the set of edges performing relations between objects.

Each edge in **E** is a tube (*Attrs, Properties, Start, End*), in which, *Attrs* is a set of attributes of a relation, *Properties* is a set of properties of the corresponding relation, *Key* is a set of keyphrases related to the corresponding relation, *Start* is a start vertex of the corresponding relation, and *End* is an end vertex of the corresponding relation. Each edge represents a relation that impacting directly from the *Start* vertex to the *End* vertex arbitrary.

3.2.2 Inference Engine

The inference engine is a component to do things on knowledge base, such as reasoning, searching, and generating intellectual multiple choices tests. This section presents problems for querying on knowledge base and generating tests automatically. It also designs algorithms for solving those problems.

3.2.2.1 The Problems for Querying On the Knowledge Base

This section discusses how an intelligent search system can conduct various types of knowledge searches, such as finding concepts, knowledge relationships, and relevant information to current research. Additionally, it proposes potential solutions to tackle the challenges associated with ontology-based knowledge domain intelligent searches.

- Searching knowledge content: The meaning of the user's inquiry is used to generate the search results.
- Searching for information about a knowledge domain's classification: The search results are categorized based on different types of knowledge, such as concepts, relationships, rules, problem types, and methods for solving them.
- Searching for related knowledge: This type of search automatically returns knowledge that is related to the current search query, helping users to find the required information.

Determining the appropriate access information for the knowledge content is worked based on the course knowledge structure organized according to ontology Rela-Graph. The knowledge base K has the structure of integrating model Rela-Graph ontology as Definition 3.1, and the searching content q. The general algorithm determining a set of knowledge, which match the content of the q for three above problems, is as follows:

Algorithm 3.1: Determining the knowledge content of searching
Input: The knowledge base K = **(C, R, Rules)** ⊕ $\mathbf{G_{KG}}$ as Rela-Graph ontology. The query sentence q. **Output:** Set of knowledge in K which match to the query q.
Step 1: Initialize *S:* = *keyword*(q). *Known*: = {} // set of returned results.

Search: = *Com*(K)

Step 2: Define the conceptual component
For *comp* **in** *S* **do**
For *item* **in** *comp* **do**
If (*item.Name* $*$ *S* $\neq\emptyset$) **then**
Known := *Known* + {*item*}
Else if (*item.Intellectual* $*$ *S* $\neq\emptyset$**) then**
Known := *Known* + {*item*}

Step 3:

Classifying *Knowledge* into categories according to the components of the Query-Onto.

Step 4: Display results as knowledge content has been classified
For *item* **in** *Known* **do**
Show *item.Content*;

Note: In Step 2, the operations $*$ và + are the intersection and union operations between two sets in the sense of "matching words", respectively [14].

3.2.2.2 The Problem About Generating a Test Automatically

Definition 3.2: Let *T* be a set of multiple-choice questions of a course. Each question in *T* has the structure as follows:

- The structure of each question *ques* $\in$ *T* is:

$$ques = (cont, Ans, correct, Ts, Les, dif)$$

where, *cont* is a content of the question (text), *Ans* is a set of answers, *correct* is a correct answer *(correct* $\in$ *Ans)*, *Ts* is a set of topics, *Les* represents lessons relating to this question, *dif* is the difficulty of the question *ques*. The first four levels of Bloom's Taxonomy [25] are used to gauge how difficult a question is. They include: "*Remembering*", "*Understanding*", "*Applying*", "*Analyzing*". The difficulty is computed by [26].

- A model of a test is a tube:

$$(S_{\mathrm{Az}}, S_{Ap}, S_U, S_R, D)$$

in which, S_{Az}, S_{Ap}, S_U *and* S_R a are the sets of questions which are "*Analyzing*", "*Applying*" "*Understanding*" and "*Remembering*" levels, resp. *D* is the difficulty level of a test. There are three categories for test difficulty: easy, normal, hard. The ratios of each type of questions are shown in Table 2 for each test.

Table 2 - Proportions for each question kind

Level of a test	Proportion			
	Analyzing	***Applying***	***Understanding***	***Remembering***
Hard	0.2	0.3	0.3	0.2
Average	0.1	0.2	0.4	0.3
Easy	0.1	0.1	0.3	0.5

Definition 3.3: The problem about generating a test automatically is denoted:

$$(num, meas, un, topics) \rightarrow (S_{\mathrm{Az}}, S_{Ap}, S_U, S_R, D)$$

In which, *num* is the number of questions in the test, *meas* is the difficulty level of the test (easy, normal, hard), *un* is the set of units which want to test; *topics* is the set of topics which want to test.

$(S_{\mathrm{Az}}, S_{Ap}, S_U, S_R, D)$ is a test as Definition 3.2 satisfying (*num, meas, un, topics*).

Algorithm 3.2: *Solve the problem about generating a test automatically.*

Let the knowledge base K as Rela-Graph Ontology Definition 3.1, and list of conditions of a test (*qu, md, sc, kn*) as Definition 3.3. This algorithm creates a test satisfying these conditions:

$$(num, meas, un, topics) \rightarrow (S_{\mathrm{Az}}, S_{Ap}, S_U, S_R, D)$$

Algorithm 3.2
Input: *num, meas, un, topics* **Output:** $(S_{\mathrm{Az}}, S_{Ap}, S_U, S_R, D)$
Step 1: From *num* and *meas*, determine the cardinality of each set S_{Az}, S_{Ap}, S_U, S_R based on the proportion in Table 2.

Step 2: • Randomly select questions from the repository of questions Q following S_{Az}, S_{Ap}, S_U, S_R. • Based on $K.G_{KG}$, these selected questions satisfy the conditions about units *un* and *topics*. **Step 3:** Selected questions mixed in S_{Az}, S_{Ap}, S_U, S_R. **Step 4:** Create a test for the user.

3.2.3 Tracing System

The intelligent system in education can support to follow the studying of students through their test results and accelerator their actions on searching. It collects contents and results from the user' testing and querying. Based on them, the system can evaluate the development of the knowledge of students.

Definition 3.4: The problem for diagnosing the knowledge of a user through is denoted:

$$(Prof,\ Qs) \rightarrow Evaluation$$

where, *Prof* is information/profile of the user, *Qs* is the set of questions which the user had done.

Considering the test's collection of correct and erroneous responses, the system will give *Evaluation* to the user: the score of the test, which is an assessment of the subject-matter expertise of the user. The system will also enter the test results into the knowledge base. The purpose of this work is to promote the user's growth in understanding of each issue in the subsequent challenge.

Definition 3.4: Let a topic k, a user had done m multiple choices tests and all tests have some questions about topic k. The problem for evaluating the development of this user about topic k is denoted by:

$$[t_1, t_2, \ldots, t_m], \text{ topic } k \rightarrow Pr_k$$

where, t_j is the j^{th} test as Definition 3.2. and $Pr_k = eval(P_k(t_1), P_k(t_2), \ldots, P_k(t_m))$ is the evaluating results for the test-process of this user, where $P_k(t_j)$ be the ability of the user on the topic k at the j^{th} test

$$P_k(t_j) = \frac{score_k(t_j)}{card(\{q_k \mid q_k \in t_j, q_k \text{ related topic } k\})} \quad (1)$$

$score_k(t_j)$ is the total score of questions in t_j which related to topic k.

$$eval\left(P_k(t_1), P_k(t_2), ..., P_k(t_m)\right) = \sum_{j=1}^{m-1}\left(P_k\left(t_{j+1}\right) - P_k\left(t_j\right)\right) \quad (2)$$

The followed algorithm will determine the development of the user's knowledge on a topic.

Algorithm 3.3: *Solve the problem for evaluating the development of the user's knowledge on each topic.*

Algorithm 3.3
Input: $[t_1, t_2, \ldots, t_m]$, topic k **Output:** the development of this user on the topic k.
Step 1: Compute $P_k(t_j)$ being be the ability of the user on topic k at the test t_j by formula (1) $(1 \le j \le m)$. **Step 2:** Compute $Pr_k = eval(P_k(t_1), P_k(t_2), \ldots, P_k(t_m))$, where $eval(P_k(t_1), P_k(t_2), \ldots, P_k(t_m))$ is computed by formula (2). **Step 3:** • Visualize values $P_k(t_1), P_k(t_2), \ldots, P_k(t_m)$. • Based on the graph and Pr_k, diagnose the development of the ability of the user about topic k through m tests. + If $Pr_k > 0$: the knowledge level of the user is increasing in topic k. + If $Pr_k < 0$: the knowledge level of the user is decreasing in topic k. + If $Pr_k = 0$: there is no development of the user's knowledge in topic k.

4. Discussion

Education technology, or edtech, is the practice of integrating information and communication technology tools into the classroom to produce more interactive, inclusive, and personalized learning experiences [27]. Edtech refers to a broad range of tools that can improve the delivery of educational information and promote student engagement and interaction, including educational software, digital textbooks, online learning platforms, virtual and augmented reality, gamification, and other digital tools [28, 29].

In [30], Nguyen *et al.* proposed criteria of knowledge model for building intelligent problem solver in STEM education. Those criteria did not mention the abilities of querying on knowledge base. The study in [26] presented a method for solving a system to evaluate the knowledge level of users in high-school mathematics through multiple choice test. However, that study did not explain required criteria for that kind of system.

This study proposed general criteria for an intelligent educational system as well as requirements for each function about querying on course's knowledge content and measuring the knowledge level of learners through testing. These criteria have been applied to design an architecture of an intelligent educational system and their compulsory components: knowledge base, inference engine and tracing system. The designed solution is useful for constructing completely intelligent systems in education, in which, the user can combine the review of lessons in a course and test their understanding level in a determined topic as well as be active in controlling their learning process.

5. Conclusions and Future works

This paper proposed the requirements of an intelligent educational system. These criteria focus two main functions of the system, including searching/querying on course content knowledge and assessing learners' knowledge proficiency through multiple-choice exams. This study also offered a method for organizing the knowledge base, inference engine, and tracing system based on a knowledge model that combines ontology and knowledge graph. The ontology for relational knowledge and knowledge graph is integrated in the knowledge model known as Rela-Graph ontology. The problems with the inference engine and the tracing system are researched and resolved based on the Rela-Graph ontology. These issues include automatically creating multiple choice assessments, searching/querying on the knowledge domain, and testing the learners' knowledge levels.

The study on building intelligent educational systems is still having many approaches for development to apply in the practice. In the future, the intelligent problem solver in education [31, 32] will be integrated. The integration makes the system can help students to solve exercises by tutoring how to solve them [33, 34]. Moreover, the architecture of chatbot will be studied to make the conversation between learners and the system being more convenient [35].

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