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LEARNING RESOURCES RECOMMENDATION FRAMEWORK USING RULE-BASED REASONING APPROACH

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ABSTRACT

Current e-learning systems present instruction in a "one-size-fits-all" style that provides the same learning resources to each student. In fact, each learner has a different learning style or different individual needs, so many learners may have difficulty gathering the most suitable learning resources for themselves. To help solve this problem, this paper presents a learning resources recommendation framework using rule-based reasoning approach which allows teachers and learners to create learning resources in the form of learning objects based on ontology for searching and reusing learning objects. This paper presents the experiment of recommendation system to provide learning resources that are appropriate to the learning style of each student by designing learner profiles and learning styles in the form of ontology. This system expresses the Web Ontology Language. (OWL), and relies on rule-based reasoning engine to identify the optimized learning resources. With the evaluation of experiments, the results showed that the learning resources recommendation based on rule-based approach retrieved the strong selection of the relevant resources.

Keywords: *Ontology, Learner Profile, Learning Styles, Learning Resources, Semantic Search, Rule-Based Reasoning*

1. INTRODUCTION

In the last decade, e-learning has become one of the most popular teaching and learning methods [1]. One of the main purposes of e-learning system is to allow teachers to define and manage contents and learning resources on the web, which will then be provided to learners. This approach is called “one-size-fits-all” [2, 3], providing the same learning resources to each student. In fact, each learner has a different learning style or different individual needs, so many learners may have difficulty gathering the most suitable learning resources for themselves. With increased learning resource dissemination on the Internet, learners can access more learning resources through e-learning systems [4]. These further resources which conform to courses are not only useful for the learners who have found them but also benefit other classmates. Thus, sharing more resources leads to increasing more effectiveness in learning. Recently, knowledge management tools have been used to improve e-learning activities. The advances in Web 2.0 are changing the concept about World-Wide-Web (WWW) regarding the inclusion of semantics in web documents and media [5]. In the context of education, using semantics to define metadata for describing learning resources leads to more meaningful sharable and searchable learning resources that meet the learners' needs. This can enhance the effectiveness of learning.

Much research has presented new frameworks of e-learning systems that help students access learning resources that correspond to their individual learning styles and needs. There are two popular methods that are applied to e-learning systems toward providing the best learning environment. They are: adaptive learning [3] and personalized learning [6].

Adaptive learning focuses on the recommendation system that suggests learning resources to suit the learning styles of learners. On the other hand, personalized learning focuses on the individual needs of learners in searching the learning resources. An example is a research-proposed [3] adaptive learning object recommendation system, using an attribute-based ant colony system, which is focused on recommended learning resources based on the characteristics of different types of learning, such as learning style and level of knowledge. The research [7] has presented the architecture of personalization

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in distributed e-learning environments by using characteristics and individual needs of the learner as a condition for selecting the learning resources which are open, dynamic and heterogeneous learning environment, in an e-learning network. Moreover, the architecture which is based upon multi-agent systems [8] was presented. This applied both Sharable Content Object Reference Model (SCORM) and Semantic Web ontology for creating packages of learning resources, which suit the learning styles of learners. The multi-agent systems can be integrated with LMS systems available for different platforms, result in sharing information in the systems, also using ontology to express learning content storage, learning sequencing and learning adaptation. As mentioned above, most research focused on creating learning resources that suit the learning styles of learners. By usual design, learning resources have no metadata to enable sharing, search, and reuse of learning objects.

This paper presents a learning resources recommendation framework using a rule-based reasoning approach which allows teachers and learners to establish learning resources in the form of learning objects based on ontology for searching and reusing learning objects. This paper present the recommendation system for providing the learning resources that are appropriate to the learning style of each learner by designing learner profile and learning styles in the form of ontology which uses the Web Ontology Language. (OWL), and relies on a rule-based reasoning engine [9] to identify the optimized learning resources. This framework fulfils the learners that have different learning style styles and different individual needs. Learners are provided the most suitable learning resources leading to an improvement in learning effectiveness.

The rest of this paper is organized as follows. Section 2 describes existing related literatures. Section 3 illustrates an overview of framework architecture. In section 4, the experiment and evaluation that shows the details of the approach taken in the adaptation rules establishing, and the ontology representing process is discussed. In addition, the preliminary experiment of the framework is included. Conclusion and future works are covered in section 5.

2. RELATED LITERATURES

The following describes the main concepts that are relevant to this paper.

2.1 Ontology Language

With ontology being widely used in data retrieval systems, an ontology language is necessary for representing and defining specific domain knowledge. Basically, the ontology describes concepts and relations. It consists of a hierarchical description of concepts in a domain, including descriptions of the properties of each concept and instances of concepts.

In many works [4, 10], the ontology plays an important role in the semantic resources by providing a source of any terms that can be used in metadata. RDF (Resource Description Framework) and RDF Schema (RDFS) were widely accepted as a formal language of metadata describing any resources. They talk about classes and properties (binary relations), range and domain constraints (on properties), and subclass and subproperty relations. However, there are some limits that cause difficulties in automated reasoning process. A new web ontology language, namely OWL (Web Ontology Language) is developed based on the RDF model. It is now officially recommended as ontology language for the Semantic Web by W3C.

OWL uses the same syntax as RDF/RDFS to represent ontology. An OWL ontology, also consists of definitions and descriptions of concepts (or classes) and relations (or properties) between them. As an extension of RDF/RDFS, OWL uses some basic elements of RDF/RDFS such as rdf:subClassOf, rdfs:domain, etc. It also provides elements of the language which have specific semantics for defining classes, properties and describing their hierarchy and also their properties. OWL defines all classes in form of owl:class. The properties are of two main types following: owl:DatatypeProperty and owl:ObjectProperty. A datatype property is a binary relation that relates an individual of class to a standard data type defined according to XML Schema datatypes (xsd) such as integer, string. On the other hand, an object property relates individuals of classes (or of a same class).

2.2 Standard Metadata

2.2.1 Dublin Core(DC) and Learning Object Metadata standard(LOM)

Since metadata has an ability to facilitate interoperability and to increase reusability, it is increasingly used to define educational materials. There are two well-known adoptions of standard metadata used to describe e-Learning resources: Dublin Core (DC) [11] and Learning Object Metadata Standard (LOM) [12]. The DC element set defines a set of basic metadata elements

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cataloguing conventional library items and also arbitrary electronic resources [4]. DC includes a set of 15 elements for descriptions: Title, Creator, Subject, Description, Publisher, Contributor, Date, Type, Format, Identifier, Source, Language, Relation, Coverage and Rights. Although DC is designed for describing any kind of resources, learning resources are disregarded. Thus, LOM metadata was established as an extension of DC which consists of nine categories: General, Lifecycle, Meta-Metadata, Technical, Educational, Rights, Relations, Annotations and Classification.

2.2.2 IMS Learner Information Package (IMS/LIP)

Using metadata in e-learning domains describes not only learning resources but also learners. IMS Learner Information Package (IMS/LIP) [13] was published, which is based on a data model that describes the characteristics of a learner [14]. IMS/LIP is a structured information model which contains both data and metadata about that data, such as the name of a learner, a course or training completed, and a learning objective. The Learner information is separated into eleven main categories: Identification, Goal, Qualifications, Certifications and Licenses (qcl), Activity, Transcript, Interest, Competency, Affiliation, Accessibility, Securitykey and Relationship.

2.2.3 Kolb's Learning Styles

Several authors have proposed different definitions for learning styles. Examples include Kolb's Experiential Learning Model [15], The Felder-Silverman Model [16, 17], Dunn and Dunn learning style model [18], Honey and Mumford model based on [19]. In our proposed, we applied the theory of Kolb which categorized learners into four distinct learning styles based on a four-stage learning cycle [3] as follows: Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC) and Active Experimentation (AE) and a four-type definition of learning styles, each representing the combination of two preferred styles, rather like a two-by-two matrix of the four-stage cycle styles, for which Kolb used the terms: Diverging (CE/RO), Assimilating (AC/RO), Converging (AC/AE) and Accommodating (CE/AE) as illustrated in Figure 1. These characteristics are shown in Table 1.

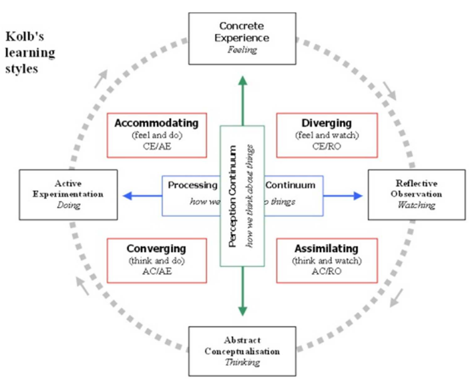

Figure 1: A Diagram of Kolb's Learning Styles [3]

3. PROPOSED FRAMEWORK

This paper proposes a learning resources recommendation framework using rule-based reasoning approach. The proposed framework consists of three main layers, namely, the presentation layer, the mediator layer and the resource layer as shown in Figure 2. The presentation layer is user interfaces that used by learners and teachers. Mediator layer is the middle connection between presentation layer and resource layer. The last, resource layer collects resources such as learner profiles and learning resources. Each layer is explained as follows:

3.1 Presentation Layer

The presentation layer is divided into 2 parts. The first part is learner interface, used by the learners, who sign up by entering the personal registration in order to create the personal profiles. When each learner is logged in, the learner interface not only shows suitable learning resources based on the learner's specific learning style but also allows learner to offer the relevant learning resources for recommendation to other learners. The second part is teacher interface, used to manage the courses, lessons and learning resources by teacher.

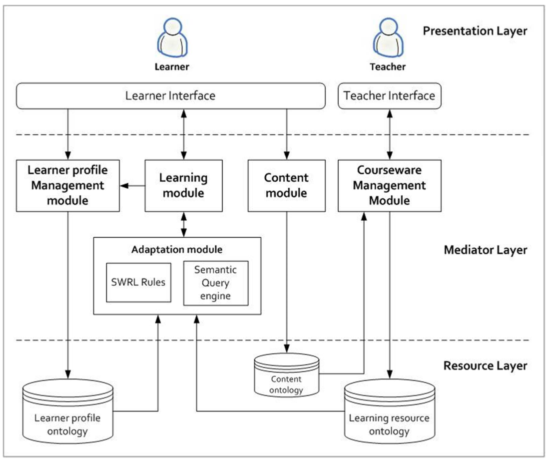

Figure 2: Learning Resources Recommendation Framework

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Table 1: Characteristics of Kolb's Learning Styles

Learning Styles	Characteristics	Learning object
Diverging (Concrete Experience / Reflective Observation)	- prefer to watch rather than do - tending to gather information - use imagination to solve problems - look at things from different perspectives	- animation - charts - graphs - low charts - symbols
Assimilating (Abstract Conceptualization / Reflective Observation)	- prefer a concise, logical approach - require good clear explanations rather than practical opportunity - ideas and concepts are more important than people	- audio - video - lectures - verbal tutorials
Converging (Abstract Conceptualization / Active Experimentation)	- use their learning to find solutions to practical concerns - prefer to work by themselves	- text-based materials, such as Microsoft office - web pages
Accommodating (Concrete Experience / Active Experimentation)	- tend to rely on others for information rather than carry out their own analysis	- experience shared - practice activities - tutorials on web - web pages

3.2 Mediator Layer

Mediator layer is the middle connection between the presentation layer and the resource layer which consists of 5 modules. It starts from the learner profile management module for personal registration. When learners are registered, their learning styles need to be tested by answering an instrument, the Learning Style Inventory (LSI) based upon Kolb's learning styles, which it used to determine his/her preferred learning style. This information is stored in the learner profile ontology, which will be used for in adaptation module. Next, content module allows learners to add the relevant learning resources which are extracted as content ontology. The courseware management module allows teachers to manage the courses, lessons and learning resources; and to approve the relevant learning resources adding by learners. These data are stored in learning resource ontology. The last module, the adaptation module, is the main module of the mediator layer. It provides learning resources that support learning style of current learner which is stored in learner profile ontology. This module applies SWRL rules to produce the adaptive rules and utilized SPARQL in Semantic Query Engine to query the suitable learning resources to learning module. Moreover, the learning module allows learners to search any relevant learning resources.

3.3 Resource Layer

The resource layer is provided as data collection for ontology extraction in the mediator layer. These ontologies are expressed by the ontology description language OWL. There are 3 resources: learner profile ontology, learning resource ontology and content ontology, which need this framework, and are explained as follows:

3.3.1 Learner profile ontology

Learner profile ontology stores personal information about learners, shown in Figure 3. The ontology is defined as classes, namely the Learner class which is related to the PersonalInfo and LearningStyle class through the hasInfomation and hasLearningStyle properties as an object property. The PersonalInfo class is defined ims-lip:id, ims-lip:name, ims-lip:email and ims-lip:mobile properties as datatype property, and related to the Department class through the object property, studyIn. The KnowledgeLevel class represents a knowledge level of each learner which is one of the learners' preferences. This class is defined hasKnowledgeLevel property as datatype property. The LearningStyle class represents the learning style for particular learners. This class offers four categories based on Kolb's learning style model which are defined as subclass, DivergingStyle, AssimilatingStyle, ConvergingStyle and AccomodatingStyle class.

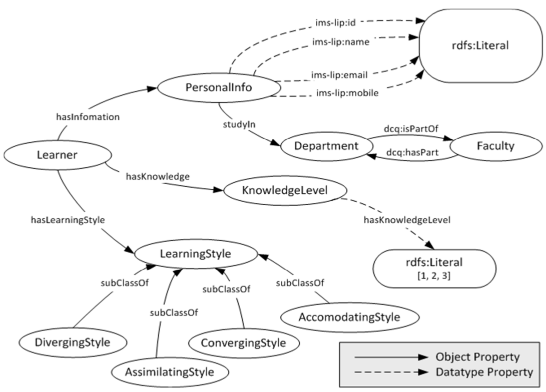

Figure 3: Learner Profile Ontology

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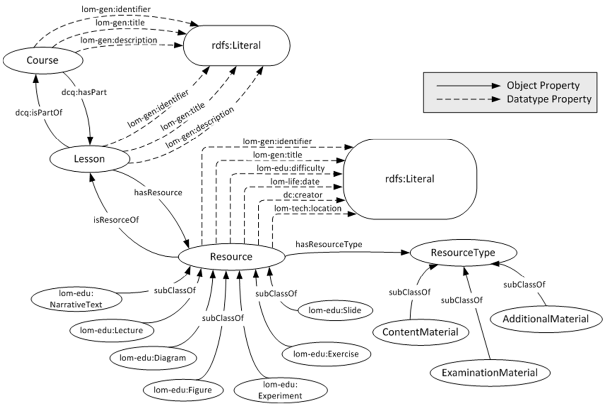

Figure 4: Learning resource ontology

3.3.2 Learning resource ontology

Learning resource ontology stores learning resources in this framework that is shown in Figure 4. The Course class is related to the Lesson class through the object property named dcq:hasPart property, and is defined lom-gen:identifier, lom-gen:title and lom-gen:description as a datatype property. The Lesson class, then, is related to the Resource class through the hasResource property. Also, it is defined three datatype properties like Course class. The Resource class is defined lom-gen:identifier, lom-gen:title, lom-edu:difficulty, lom-life:date, lom-tech:location and dc:creator as datatype property, and is related to the ResourceType class through the hasResourceType property. It consists of many subclasses that represent the type of resources as follows : lom-edu:NarrativeText, lom-edu:Slide, lom-edu:Diagram, lom-edu:Figure, lom-edu:Lecture, lom-edu:Exercise, lom-edu:Experiment. The ResourceType class explains the kinds of learning resources such as content material, examination material, and additional material.

3.3.3 Content ontology

Content ontology stores the relevant learning resources which are added into this framework by learners. The structure of this ontology is similar to the learning resource ontology. Content ontology has only one kind of learning resource that is additional to resources in the ResourceType class.

4. RELATED LITERATURES

4.1 Establishing Individual Relationships and Adaptation Rules using SWRL Rule

In this part is the establishing of a rule in order to create a relationship between learner profiles and learning resources. This relationship will be the important key in helping to search for learning resources which meet the learners' characteristics most efficiently. According to the definition of the ontological learner profiles and learning resources, both ontology structures have not been related. This research focuses on three ways of relation building: 1) a relationship between the resource class in the learning resource ontology and the learning style class in the learner profile ontology, 2) a relationship between the resource class in learning resource ontology and the learner in learner profile ontology. And 3) a relationship between the knowledge level class in the learner profile and the learner class in learning resource ontology. These can be described as follows:

4.1.1 A relationship between resource class in the learning resource ontology and learning style class.

Owing to the learning styles of learner being divided into four categories, with each category having a favourite style of learning, as shown in Table 1, it is therefore necessary to create a rule in order to build the relationship in terms of object property between the resource class in the learning resource ontology and the learning style class. The resource has an object property named 'support', has as its domain the resource class, and its range is the learning style, as shown in Figure 5. Established rules that support the relationship shown in Table 2.

4.1.2 A relationship between resource class in learning resource ontology and learner in learner profile ontology.

After a relationship of support has been created, the relationship in the next sequence suggests resources which are appropriate to learning styles by using the support relationship to determine this connection. An established rule that supports the relationship is shown in Table 3.

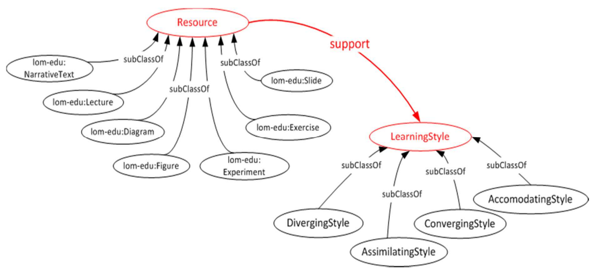

Figure 5: Object Property : support

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Table 2: Reasoning Rules For Defining Object Property : support

Rule No.	Reasoning Rules	Description
R1	lom-edu:Diagram(?r) ∧ csKKU:DivergingStyle(?s) → csKKU:support(?r, ?s)	If resource is type of diagram then it supports learning style in type of diverging style
R2	lom-edu:Figure(?r) ∧ csKKU:DivergingStyle(?s) → csKKU:support(?r, ?s)	If resource is type of figure then it supports learning style in type of diverging style
R3	lom-edu:Lecture(?r) ∧ csKKU:AssimilatingStyle(?s) → csKKU:support(?r, ?s)	If resource is type of lecturer then it supports learning style in type of assimilating style
R4	lom-edu:NarrativeText(?r) ∧ csKKU:ConvergingStyle(?s) → csKKU:support(?r, ?s)	If resource is type of narrative text then it supports learning style in type of converging style
R5	lom-edu:Slide(?r) ∧ csKKU:ConvergingStyle(?s) → csKKU:support(?r, ?s)	If resource is type of slide then it supports learning style in type of converging style
R6	lom-edu:Exercise(?r) ∧ csKKU:AccommodatingStyle (?s) → csKKU:support(?r, ?s)	If resource is type of exercise then it supports learning style in type of accommodating style

Table 3 : Reasoning Rules For Defining Object Property : suggestTo

Rule No.	Reasoning Rule	Description
R7	csKKU:support(?r, ?s) ∧ csKKU:hasLearningStyle(?l, ?s) → csKKU:suggestTo(?r, ?l)	If resource has supported learning style which is the same with the learning style of learner then resource is suggested to learner

4.1.3 A relationship between knowledge level class in the learner profile and learner class in learning resource ontology.

After the support and suggest relationship have been created, a next relationship to be considered are from the data property, hasKnowledge, of the learner and the data property, lom-edu:difficulty of the resource. While the resource has an object property named 'provideTo', the domain is resource class and the range is learner, shown in Figure 6. An established rule that supports the relationship shown in Table 4.

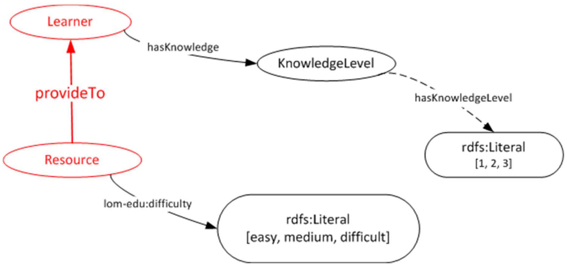

Figure 6: Object Property : provideTo

The above adaptation rules can be executed using the JESS rules engine after providing the factual knowledge. After firing the rule, the inferred knowledge can be written back to the ontology repository [20].

Table 4 : Reasoning Rules For Defining Object Property : provideTo

Rule No.	Reasoning Rules	Description
R8	csKKU:hasKnowledge(?l, ?k) ∧ csKKU:hasKnowledgeLevel(?k, 1) ∧ lom-edu:difficulty(?r, "easy") → csKKU:provideTo(?r, ?l)	If resource has difficulty in easy level, then resource provides to learner who has knowledge in level 1.
R9	csKKU:hasKnowledge(?l, ?k) ∧ csKKU:hasKnowledgeLevel(?k, 2) ∧ lom-edu:difficulty(?r, "easy") → csKKU:provideTo(?r, ?l)	If resource has difficulty in easy level or medium level, then resource provides to learner who has knowledge in level 2.
R10	csKKU:hasKnowledge(?l, ?k) ∧ csKKU:hasKnowledgeLevel(?k, 2) ∧ lom-edu:difficulty(?r, "medium") → csKKU:provideTo(?r, ?l)	
R11	csKKU:hasKnowledge(?l, ?k) ∧ csKKU:hasKnowledgeLevel(?k, 3) ∧ lom-edu:difficulty(?r, "easy") → csKKU:provideTo(?r, ?l)	If resource has difficulty in easy level or medium level or difficult, then resource provides to learner who has knowledge in level 3
R12	csKKU:hasKnowledge(?l, ?k) ∧ csKKU:hasKnowledgeLevel(?k, 3) ∧ lom-edu:difficulty(?r, "medium") → csKKU:provideTo(?r, ?l)	
R13	csKKU:hasKnowledge(?l, ?k) ∧ csKKU:hasKnowledgeLevel(?k, 3) ∧ lom-edu:difficulty(?r, "difficult") → csKKU:provideTo(?r, ?l)	

4.2 Representing the domain model using OWL ontology

To evaluate the generated adaptation rules, it is necessary to represent learner profiles and learning resources, for which this research has determined some data, in order to test with 20

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ontological learner profiles and 48 learning resources as shown in Figure 7-8.

```
<Learner rdf:ID="_5550200324">
    <hasInformation rdf:resource="#pi5550200324"/>
    <hasKnowledge rdf:resource="#KnowledgeLevel_3"/>
    <hasLearningStyle rdf:resource="#Accommodating"/>
 </Learner>
    ......
<PersonalInfo rdf:ID="pi5550200324">
    <studyIn rdf:resource="#ComputerScience"/>
    <ims-lip:id rdf:datatype="&xsd;string">5550200324
    </ims-lip:id>
    <ims-lip:email rdf:datatype="&xsd;string">
        xxx@cs-ubru.edu</ims-lip:email>
    <ims-lip:mobile rdf:datatype="&xsd;string">085-0200324
    </ims-lip:mobile>
    <ims-lip:name rdf:datatype="&xsd;string">
        XXX XXX</ims-lip:name>
    .....
</PersonalInfo>
    ......
<KnowledgeLevel rdf:ID="KnowledgeLevel_3">
    <hasKnowledgeLevel rdf:datatype="&xsd;int">3
    </hasKnowledgeLevel>
</KnowledgeLevel>
    ......
<AccommodatingStyle rdf:ID="Accommodating"/>
<owl:Class rdf:ID="AccommodatingStyle">
    <rdfs:subClassOf rdf:resource="#LearningStyle"/>
</owl:Class>
```

Figure 7: Excerpt Of Ontological Learner Profiles

```
<lom-edu:Diagram rdf:ID="diag4122304005">
    <hasResourceType rdf:resource="#ContentMaterial_1"/>
    <isResourceOf rdf:resource="#Lesson_01"/>
    <dc:creator rdf:datatype="&xsd;string">YYY YYY
    </dc:creator>
    <lom-edu:difficulty rdf:datatype="&xsd;string">easy
    </lom-edu:difficulty>
    <lom-gen:identifier rdf:datatype="&xsd;string">
        4122304005</lom-gen:identifier>
    <lom-gen:title rdf:datatype="&xsd;string">
        Variable and Namimg</lom-gen:title>
</lom-edu:Diagram>
    ......
<lom-edu:Lecture rdf:ID="lec4121304003">
    <hasResourceType rdf:resource="#ContentMaterial_1"/>
    <isResourceOf rdf:resource="#Lesson_01"/>
    <dc:creator rdf:datatype="&xsd;string">ZZZ ZZZ
    </dc:creator>
    <lom-edu:difficulty rdf:datatype="&xsd;string">easy
    </lom-edu:difficulty>
    <lom-gen:identifier rdf:datatype="&xsd;string">
        4121304003</lom-gen:identifier>
    <lom-gen:title rdf:datatype="&xsd;string">
        Variable and Namimg</lom-gen:title>
</lom-edu:Lecture>
```

Figure 8: Excerpt Of Ontological Learning Resources

```
PREFIX   csKKU:<http://www.owl-ontologies.com/OntoLO.owl#>
PREFIX   ims-lip:<http://www.imsglobal.org/xsd/imslip_v1p0#>
SELECT   ?resource ?loTitle
WHERE {  ?resource csKKU:suggestTo csKKU:_5550200873.
         ?resource csKKU:provideTo csKKU:_5550200873.
         ?resource lom-gen:title ?loTitle.
}
```

Figure 9: Using SPARQL To Search The Resources For Learner ID = 5550200873

4.3 Query for suggestion

In the experiment, individual relationships and adaptation rules using SWRL rule were established and the domain model was represented. Figure 9 shows the example of SPARQL query language used to examine the results using the SPARQL tab in Protégé tool. Some results are inferred from adaptation rules provided in the previous section. The results are shown in Figure 10.

Results

resource	loTitle
csKKU:nar4122301001	Variable and Namimg
csKKU:nar4122301026	Numeric Type
csKKU:sld4122304004	Variable and Namimg
csKKU:nar4122304044	Datatype Conversion
csKKU:nar4122304042	Operator
csKKU:nar4122304041	Variable Declaration
csKKU:sld4122304030	Numeric Type
csKKU:sld4122304032	Character Type
csKKU:nar4122304027	Character Type
csKKU:sld4122304033	Variable Declaration
csKKU:sld4122304034	Operator

Figure 10: The Result Of Searching The Resources For Learner ID = 5550200873

4.4 Evaluation

The evaluation of the learning resource recommendation was carried out using requests for learning resources which match with different learning styles of learners and their knowledge level. The evaluation is measured using precision and recall in order to determine the retrieval efficiency. Precision means the number of learning resources retrieved that are relevant to the learner's learning styles. Recall means the number of learning resources that are relevant and are successful to the query. The F-measure is efficient overall representation of precision and recall, as shown in Table 5.

The Precision and Recall are calculated from:

$$Precision = \frac{A}{A+C} \quad (1)$$

$$Recall = \frac{A}{A+B} \quad (2)$$

As A is the number of retrieved resources that are relevant. B is the number of relevant resources

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that are not retrieved. C is the number of retrieved resources that are not relevant.

The Precision and Recall are used to obtain F-measure from :

$$F - measure = 2\left[\frac{Precision \times Recall}{Precision + Recall}\right] \quad (3)$$

Table 5: Evaluation Result

Query	Precision	Recall	F-measure
Q1	0.86	1.00	0.92
Q2	1.00	1.00	1.00
Q3	0.92	1.00	0.96
Q4	1.00	1.00	1.00

The evaluation result means that the learning resource recommendation based on rule-based approach can be retrieved the strong number of the relevant resources.

5. CONCLUSION AND FUTURE WORKS

This paper presents a learning resources recommendation framework using rule-based reasoning approach. The learning resources have metadata that forms them into learning objects that are easy to search and reuse for improving the knowledge sharing between the learners. We represented the ontological learner profiles and learning resource ontology and also adaptation rules which can provide the inferred knowledge, which is the set of learning resources that meet learners' learning styles and preferences. The learning resources recommendation including, learner profiles, can be evaluated by information retrieval measures, which give a strong result in a set of information retrieval values in different queries.

In terms of, the ontological learner profiles and learning resources, however, both structures have few data collecting about learners and their preferences. This led to the establishing of the rules in order to create the relationships is quite not much as it can be considered from learning styles and knowledge level only. According to this limitation of the presented work, in the future work, we plan to use learner profiles, including more preferences and learner's behaviour, and adjust these characteristics into the ontological learner model.

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