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Automatic and Dynamic Analysis of Learning Objects Repositories Through Ontologies and Data Mining Techniques for Supporting Personalized Recommendation of Content in Adaptive and Intelligent Educational Systems

Presentation Content

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Introduction

- **Adaptive** and **Intelligent** Educational Systems are interesting resources for **supporting** teaching-learning activities.
- Such environments make use of **intelligent techniques** to adapt educational content to the real needs of students.
- The aim is to provide a more **personalized** and **individualized** learning experience.
- With the **increasing amount of educational content**, smart data analysis will become indispensable for educational progress.
- In this context, **ontologies** and **machine learning** techniques seems to be invaluable.

Introduction

- Challenge
  - wide variation of students' profiles and the large amount of content that must be analysed.

- Given this, smart analysis of **content repositories** is an approach to be considered.

- Objective.
  - Build an approach based on **ontologies** and **data mining** to efficiently analyse learning objects based on **learning styles.**

- Hypothesis.
  - **Ontologies and clustering** algorithms may **support** the recovering and recommendation of learning objects that best fit each specific students' learning styles.

Related Work

- Qin, Jian, and Naybell Hernández. "**Ontological representation of learning objects: building interoperable vocabulary and structures.**" Proceedings of the 13th international World Wide Web conference on Alternate track papers & posters. ACM, 2004.

- Ayad, Hanan, and Mohamed Kamel. "**Clustering learning objects collections using cluster ensembles**." The 3rd Annual Scientific Conference of the LORNET Research Network (I2LOR 06). 2006.

- Shaban, Khaled, Otman Basir, and Mohamed Kamel. "**Learning Objects Clustering based on Semantic Understanding of Text**." 3rd Annual E-learning Conference on Intelligent Interactive Learning Object Repositories (I2LOR 2006). 2006.

- da Silva, Patric Ferreira, and Pollyana Notargiacomo Mustaro. "**Clustering of learning objects with Self-Organizing Maps.**" Frontiers in Education Conference, 2009. FIE'09. 39th IEEE. IEEE, 2009.

- dos Santos, Henrique Lemos, et al. "**Clustering learning objects for improving their recommendation via collaborative filtering algorithms.**" Research Conference on Metadata and Semantics Research. Springer International Publishing, 2015.

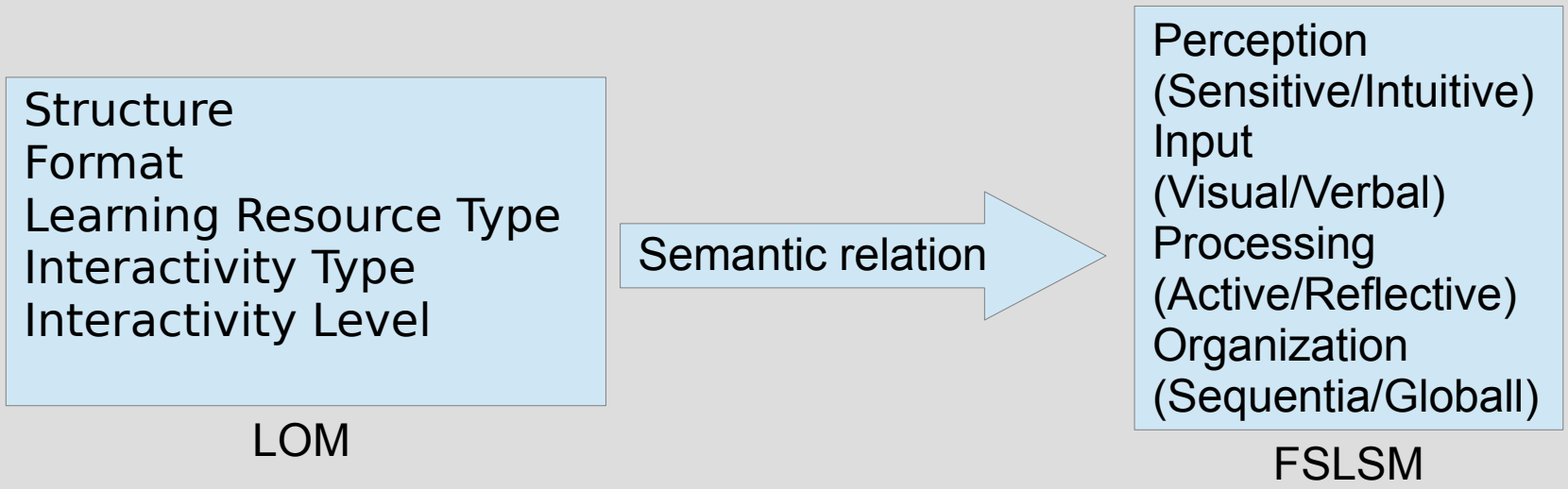
Theoretical Background

- Our approach is based on
  - IEEE Learning Object Metadata Standard (LOM)
  - Felder and Silverman's Learning Styles Model (FSLSM)
    - 4 dimensions, 2 preferences (LS) in each dimention
    - Each student tends to one preference in each dimension
  - Ontologies – knowledge representation
    - Web Ontology Language (OWL)
    - Semantic Web Rule Language (SWRL)
    - Semantic Query-Enhanced Web Rule Language (SQWRL)
  - Data mining
    - Clustering
      - K-means, Expectation Maximization (EM) and Self-Organizing Map (SOM)

Proposed Approach

- Our approach is based on an **ontology** for representation of LOs and **their relation** to LS

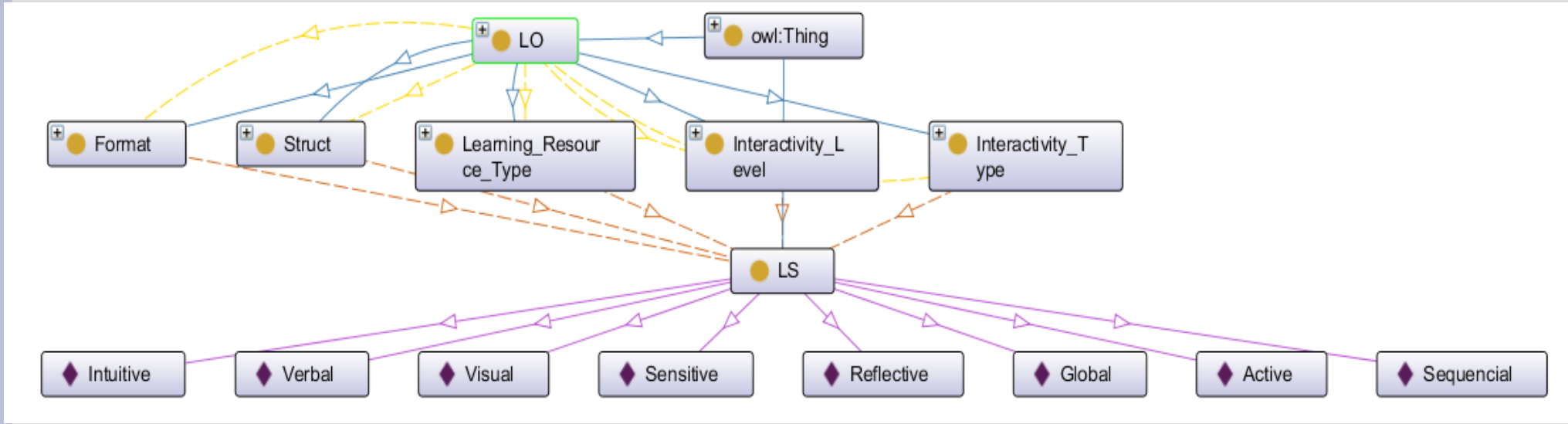
- **Pedagogical relations** between FSLSM and LOM have been defined from careful study and analysis of
  - R. Felder and L. Silverman, "**Learning and teaching styles in engineering education,**" Journal of Engineering education, vol. 78, no. 7, pp. 674–681, 1988.
  - IEEE, **LOM** (Learning Object Metadata). IEEE Learning Technology Standards Committee, http://ltsc.ieee.org/wg12/index.html, 2010.



Proposed Approach

- The ontology
  - In order to allow **using** and **sharing** this knowledge easily, an ontology was developed using OWL.

- Diagram for high-level representation of the ontology



Proposed Approach

- The LO class has five **subclasses** representing the 5 LOM fields used.
- Each subclass consists of **individuals** representing the **values** each field can receive.
- The class LS is composed only by **individuals**, where each individual represents one LS.

Proposed Approach

- Classes and individuals in the ontology

Class	Subclasses	Individuals
LS		Active, Reflective, Intuitive, Sensitive, Visual, Verbal, Sequential, Global
LO	Structure	atomic, linear, collection, hierarchical, networked
	Format	application, audio, image, text, video
	Interactivity type	active, expositive, mixed
	Interactivity level	very high, high, medium, low, very low
	Learning resource type	diagram, exam, exercise, experiment, figure, graph, index, lecture, narrative text, problem statement, questionnaire, self assessment, simulation, slide, table

- SWRL rules associates LOM fields to LS.
- Until now, a total of 58 rules were modeled.
- Each SWRL rule represents one relation between a LOM field value and a LS.

Proposed Approach

- Two properties (relationships between concepts) “has” and “is” are used to link LOM properties to LS.
- For example, the first rule states that
  - IF a LO **has** its field “Struct” filled with value “collection”, then it **is** related to the LS “Global”.

SWRL Rules	Description
has(?o, collection) ->is(collection, Global)	Attribute ”collection” (field Struct) is mapped to LS ”global”
has(?o, table) ->is(table, Sensitive)	Attribute ”table” (field LRT) is mapped to LS ”sensitive”
has(?o, table) ->is(table, Verbal)	Attribute ”table” (field LRT) is mapped to LS ”verbal”
has(?o, table) ->is(table, Reflective)	Attribute table (field LRT) is mapped to LS ”reflective”
has(?o, video) ->is(video, Visual)	Attribute video (field Format) is mapped to LS ”visual”
has(?o, video) ->is(video, Reflective)	Attribute video (field Format) is mapped to LS ”reflective”
has(?o, mixed) ->is(mixed, Active)	Attribute mixed (field IT) is mapped to LS ”active”
has(?o, mixed) ->is(mixed, Reflective)	Attribute mixed (field IT) is mapped to LS ”reflective”
has(?o, medium) ->is(medium, Active)	Attribute medium (field IL) is mapped to LS ”active”
has(?o, medium) ->is(medium, Reflective)	Attribute medium (field IL) is mapped to LS ”reflective”
...	...

Proposed Approach

- **SQWRL** rules were created in order to **count** how many SWRL rules were satisfied for each LS.

SQWRL rules	Description
LO(?o) ^has(?o, ?x) ^is(?x, Active) ->sqwrl:count(?x)	How many times the LO satisfies the LS "active"
LO(?o) ^has(?o, ?x) ^is(?x, Reflective) ->sqwrl:count(?x)	How many times the LO satisfies the LS "reflective"
LO(?o) ^has(?o, ?x) ^is(?x, Visual) ->sqwrl:count(?x)	How many times the LO satisfies the LS "visual"
LO(?o) ^has(?o, ?x) ^is(?x, Verbal) ->sqwrl:count(?x)	How many times the LO satisfies the "verbal" LS
LO(?o) ^,has(?o, ?x) ^is(?x, Intuitive) ->sqwrl:count(?x)	How many times the LO satisfies the LS "intuitive"
LO(?o) ^has(?o, ?x) ^is(?x, Sensitive) ->sqwrl:count(?x)	How many times the LO satisfies the LS "sensitive" LS
LO(?o) ^has(?o, ?x) ^is(?x, Sequential) ->sqwrl:count(?x)	How many times the LO satisfies the LS "sequential"
LO(?o) ^has(?o, ?x) ^is(?x, Global) ->sqwrl:count(?x)	How many times the LO satisfies the LS "global"

- Each rule counts **how many times** the LO (?o) was linked - through SWRL rules - to each LS

Proposed Approach

- Example

LO in the ontology

LOM field value	LOM field
has(LO, mixed)	Interactivity Type
has(LO, collection)	Struct
has(LO, video)	Format
has(LO, table)	Learning Resource Type
has(LO, medium)	Interactivity Level

Result of the ontology inferences

LOM Field values	SWRL rules satisfied by the LO
has(LO, mixed)	is(mixed, Active)
	is(mixed, Reflective)
has(LO, collection)	is(collection, Global)
has(LO, video)	is(video, Visual)
	is(video, Reflective)
has(LO, table)	is(table, Sensitive)
	is(table, Verbal)
	is(table, Reflective)
has(LO, medium)	is(medium, Active)
	is(medium, Reflective)

Proposed Approach

- The result is an **8 dimensional vector**, where each position represents the amount of SWRL rules satisfied for each LS.

- Example:

Active	Reflective	Visual	Verbal	Sequential	Global	Intuitive	Sensitive
2	4	1	1	0	1	0	1

  - This result **quantifies** how much a LO may attend a specific student, or not.

  - This LO may better support students with reflective, visual or verbal, global and sensitive preferences.

  - This data structure may
    - **support** the personalized recommendation of LOs.
    - **allow clustering of** LOs according to LS.

Proposed Approach

- **Clustering** LOs in Learning Styles Combinations (**LSCs**)
  - **LSCs**={(A,S,Vi,Seq), (A,S,Vi,G), (R,S,Vi,Seq), (R,S,Vi,G), (A,S,Ve,Seq), (A,S,Ve,G), (R,S,Ve,Seq), (R,S,Ve,G), (A,I,Vi,Seq), (A,I,Vi,G), (R,I,Vi,Seq), (R,I,Vi,G), (A,I,Ve,Seq), (A,I,Ve,G), (R,I,Ve,Seq), (R,I,Ve,G) }.
  - Therefore, **16 clusters** of LOs are possible.
- For **running clustering**, we have considered an **experimental repository** compounded by 1600 LOs (100 corresponding to each LSC).
  - Therefore, considering this **experimental repository**, the best result to be obtained is 16 clusters
    - each one composed by 100 LOs of a specific LSC.

Preliminary results

- Analysis of Results

	KMeans		EM		SOM	
C	**Qtd**	**Classes**	**Qtd**	**Classes**	**Qtd**	**Classes**
1	100	SenRefGloVis	100	SenRefGloVis	111	IntRefSeqVis , IntRefGloVis
2	100	SenRefSeqVis	100	IntRefSeqVer	89	IntRefGloVis , IntRefSeqVis
3	100	IntAtiGloVis	100	SenAtiGloVis	60	IntAtiSeqVis , IntAtiGloVis
4	100	IntAtiGloVer	100	IntAtiGloVer	140	IntAtiGloVis , IntAtiSeqVis
5	100	IntRefGloVer	100	IntAtiSeqVer	116	SenRefSeqVis , SenRefGloVis
6	34	SenAtiGloVis	100	IntRefSeqVis	84	SenRefGloVis , SenRefSeqVis
7	100	SenAtiSeqVer	86	SenAtiSeqVer	90	SenAtiSeqVis , SenAtiGloVis
8	66	SenAtiGloVis	96	IntAtiSeqVis	110	SenAtiGloVis , SenAtiSeqVis
9	119	IntRefSeqVis , IntAtiSeqVis	100	SenRefSeqVer	104	SenRefGloVer , SenRefSeqVer
10	100	SenAtiGloVer	100	IntRefGloVis	96	SenRefSeqVer , SenRefGloVer
11	100	SenAtiSeqVis	75	SenAtiSeqVis , IntAtiSeqVis	74	SenAtiSeqVer , SenAtiGloVer
12	100	IntRefGloVis	100	IntRefGloVer	126	SenAtiGloVer , SenAtiSeqVer
13	135	IntAtiSeqVis , IntAtiSeqVer	100	IntAtiGloVis	123	IntRefSeqVer , IntRefGloVer
14	100	SenRefGloVer	43	SenAtiSeqVis , SenAtiSeqVer	77	IntRefGloVer , IntRefSeqVer
15	146	IntRefSeqVer , IntAtiSeqVer	200	SenAtiGloVer , SenRefGloVer	58	IntAtiSeqVer , IntAtiGloVer
16	100	SenRefSeqVer	100	SenRefSeqVis	142	IntAtiGloVer , IntAtiSeqVer
M	**P: 0,945**	**F: 0,923**	**P:0,945**	**F: 0,928**	**P: 0,562**	**F : 0,553**

Purity (P) - evaluates the homogeneity between elements in each cluster

F-measure (F) - which evaluates the quality of each cluster based on precision and recall

Conclusions

- **Personalized** recommendation of content is a **challenge** in Adaptive Educational Systems.
- It is very **important** (and difficult) to **relate** educational **theories** with technological **solutions**, and its a **challenge** too.
- Our SWRL rules are constantly **under review**
  - Inconsistent rules may lead to inconsistent recommendation.
- The **ontology encapsulates the knowledge** about relations between LOM to LS, and it may support
  - personalized recommendation and
  - clustering of LOs.
- K-means and EM algorithms showed **good results** in clustering of LOs.

Future Work

- Extend the ontology with CLEO Extensions to the IEEE Learning Object Metadata (Customized Learning Experience Online).
- Fine tune the SWRL rules.
- Fine tune the clustering algorithm.
- Implement the proposed approach on our learning ubiquitous platform, Classroom eXperience (cx.facom.ufu.br)
  - Currently it automatically captures content and produces LOs and their metadata.

Finishing...

- The other members of the team
  - Vitor Carvalho – masters student (ontology)
  - Miller Mendes - masters student (clustering)
  - Hiran Ferreira – doctoral student (assessment and student modelling using ontology and bayesian net)
  - Rafael Araújo – doctoral student (collaborative learning and LOs automatic production)
  - Prof. Dr. Renan Cattelan
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