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Ontology Based Method of Electronic Learning Resources Retrieval & Integration

Marina Kultsova,
Anton Anikin,
Irina Zhukova

Volgograd State Technical University, Russia

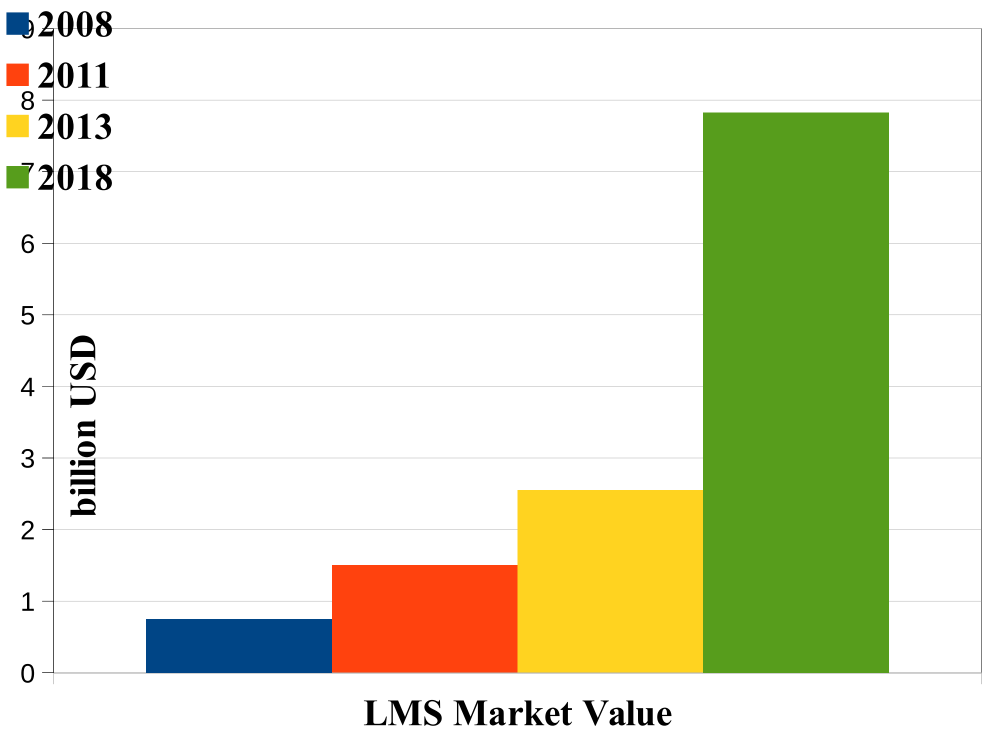
I. Introduction & State of the Art

II. Ontology-based Approach
to the Personal Learning Collection Creating

III. Ontology-based Method
for Electronic Learning Resources
Retrieval & Integration

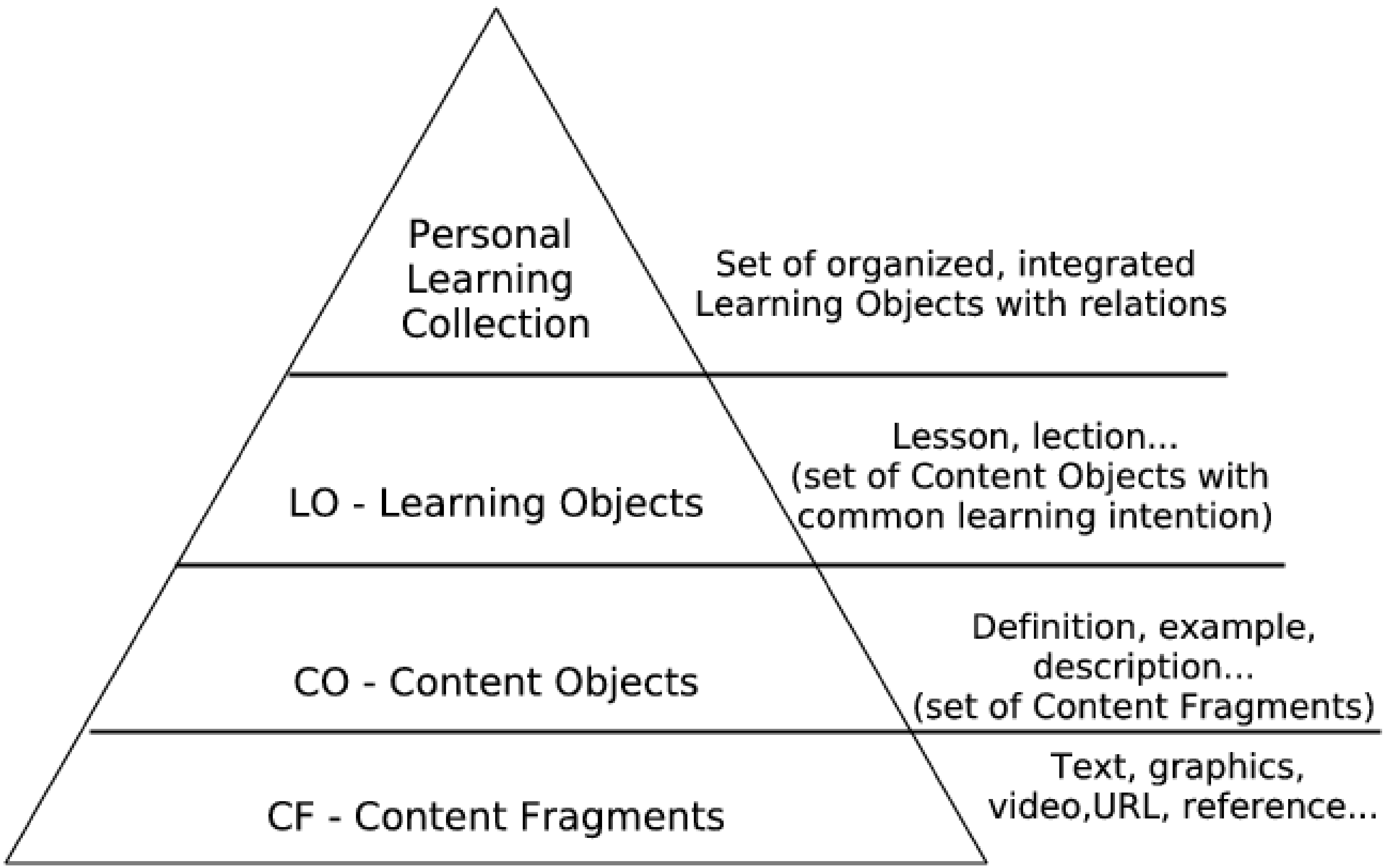
IV. Conclusion

I. State of the Art

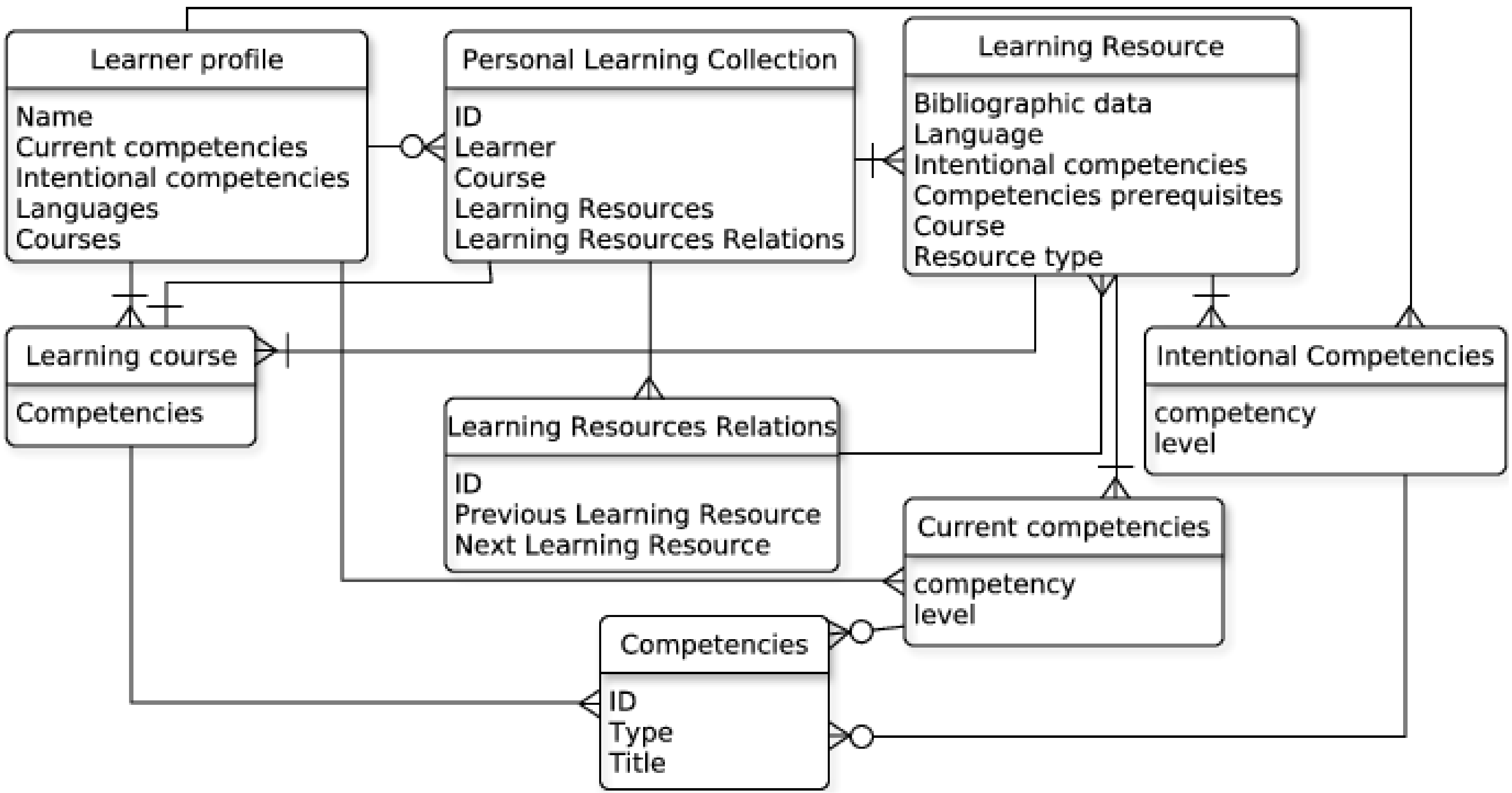


Approaches for adaptive learning resources retrieval and using	
Metadatas	LOM IEEE 1484.12.1 – 2002, DCMI
AND-OR trees	A.I.Bashmakov, I.A.Bashmakov, V.V.Kruchinin
Neural networks	P.Brusilovsky, B. Chen
Graph models, semantic networks	P.Brusilovsky, V.Shute, W.Nejdl, P.Dolog
Ontologies (Semantic Web)	P.Brusilovsky, S.Sosnovsky, W.Nejdl, N.Henze, N.Stojanovic, I.P.Norenkov, N.Pukkhem

II. Ontology Based Approach to the Personal Learning Collection Creation. Learning Resources Hierarchy



ER-diagram of subject domain (Crow's Foot notation)

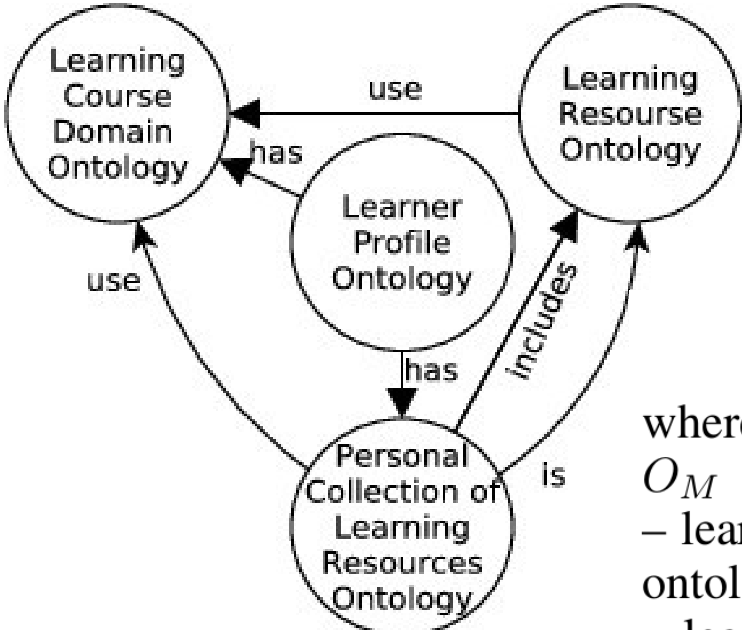


Knowledge Representation Model Requirements

- Model should be able to represent different types of semantic relations including hierarchical relations;
- Model should be modular and extensible;
- Model should support the accumulation, sharing and reusing the knowledge about objects and subjects of learning process;
- Model should provide the consistent description of domain objects.

Metaontology for the learning resources retrieval and integration into the personal collections (IDEF5)

- provides the consistency and integration of resource descriptions, data domain of the learning course, learner profile and personal electronic learning collection due to use of the common ontology domain for defining and reusing the properties of the objects and subjects of the learning process



$$M = < O_M, C, Inst, R, I >, \quad (1)$$

where M – meta-ontology;
$O_M = \{O_{DD}, O_{ELR}, O_{COL}, O_L\}$ – set of ontologies, O_{DD} – learning course domain ontology, O_{ELR} – learning resource ontology, O_{COL} – personal learning collection ontology, O_L – learner profile ontology;
C – finite set of meta-ontology concepts, $C = \varnothing$;
$Inst$ – finite set of meta-ontology instances, $Inst = \varnothing$;
$R = \{has, uses, includes, is\}$ – finite set of meta-ontology relations;
I – finite set of interpretation rules, $I = \varnothing$.

Formal problem statement of creation of the personal learning collection (¼)

Given: learner profile as a search query $Q = \langle I_q, R_q \rangle$, where I_q – set of instances defined on the ontology O_M; R_q – set of relations defined on the ontology O_M.

Set of instances: $I_q = \{i_{Q1}, i_{Q2}, ..., i_{Qn}\}$,

where $i_{Q1} \subset C_{L1}$ – instance of class C_{L1} of ontology O_L (learner);

$\{i_{Q2}...i_{QP}\} \subset C_{L2}$ – instance of class C_{L2} of ontology O_L (preferred languages);

$i_{Qi} \subset C_{L4}$ – instance of class C_{L4} of ontology O_L (current learner competences);

$i_{Qo} \subset C_{L4}$ – instance of class C_{L4} of ontology O_L (outcome learner competences);

$\{i_{Qq}...i_{Qr}\} \subset C_{DD2}$ - instances of class C_{DD2} of ontology O_{DD} (current and outcome competences defined through i_{Qi} and i_{Qo});

$\{i_{Qs}...i_{Qt}\} \subset C_{L3}$ – instances of class C_{L3} of ontology O_L (complexity level);

Formal problem statement of creation of the personal learning collection (2/4)

Set of relations: $R_q = \{r_{Q1}, r_{Q2}, ..., r_{Qm}\}$,

where $r_{Q1}(i_{Q1}, i_{Qi}) = r_{L2}$ – relation defining current learner competences on ontology O_L through i_{Qi};

$r_{Q2}(i_{Q1}, i_{Qo}) = r_{L3}$ – relation defining outcome learner competences on ontology O_L through i_{Qo};

$r_{Q3} = r_{L6}$ – relation defining preferred languages on ontology O_L;

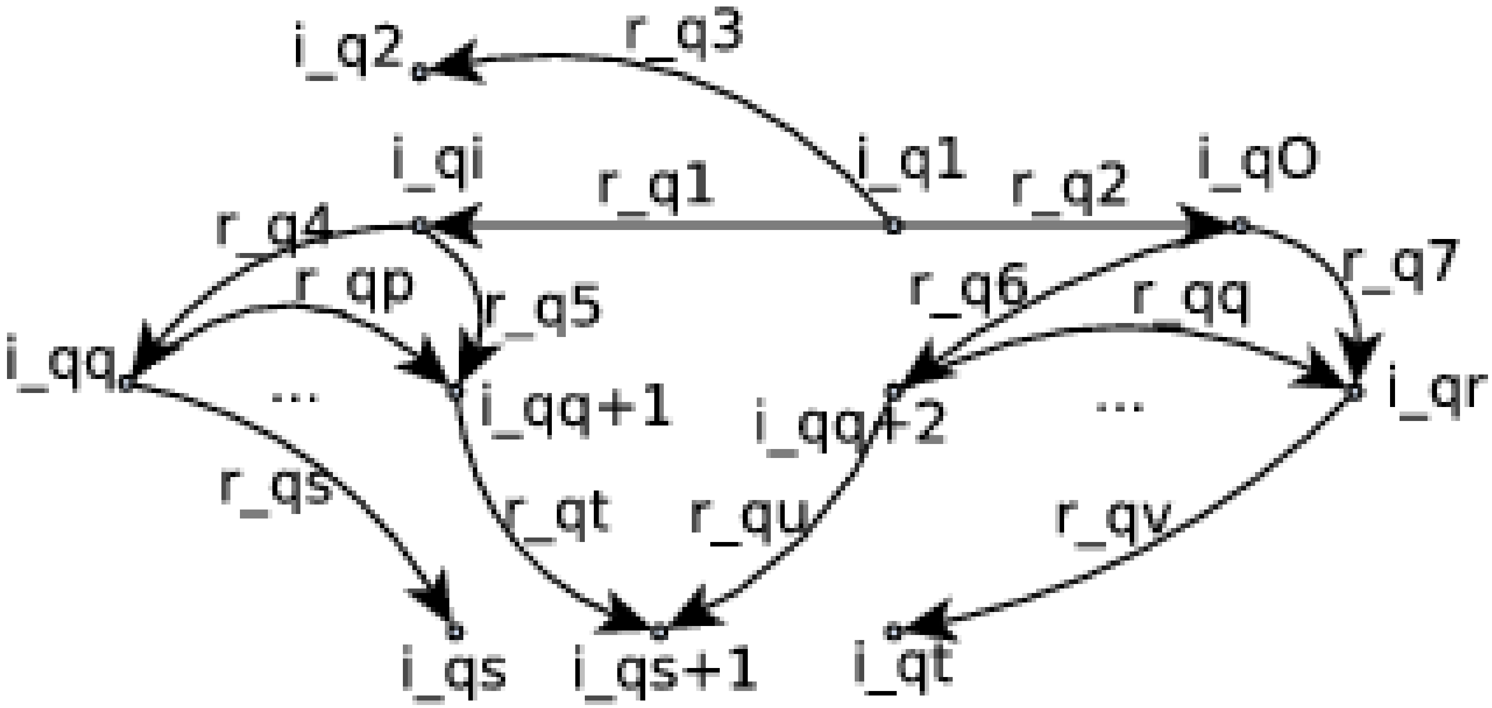
$r_{Q4} = r_{DD9} ... r_{QP} = r_{DD9}$ – relations defining current and outcome learner competences (for i_{Qi} and i_{Qo});

$r_{Qp} ... r_{Qq}$ – relations defined between the competences;

$r_{Qs} ... r_{Qt}$ – relations r_{L4} defining mastering level for current learner competences;

$r_{Qu} ... r_{Qv}$ – relations r_{L5} defining mastering level for outcome learner competences.

Formal problem statement of creation of the personal learning collection (3/4)



Ontological representation of the search query (fragment of semantic net)

Formal problem statement of creation of the personal learning collection (4/4)

Define: the personal learning collection as a fragment of semantic net $E_{COL} = \langle ER, R \rangle$, where R – set of relations $\{r_{COL3}\}$, ER – set of learning resources relevant to search query Q.

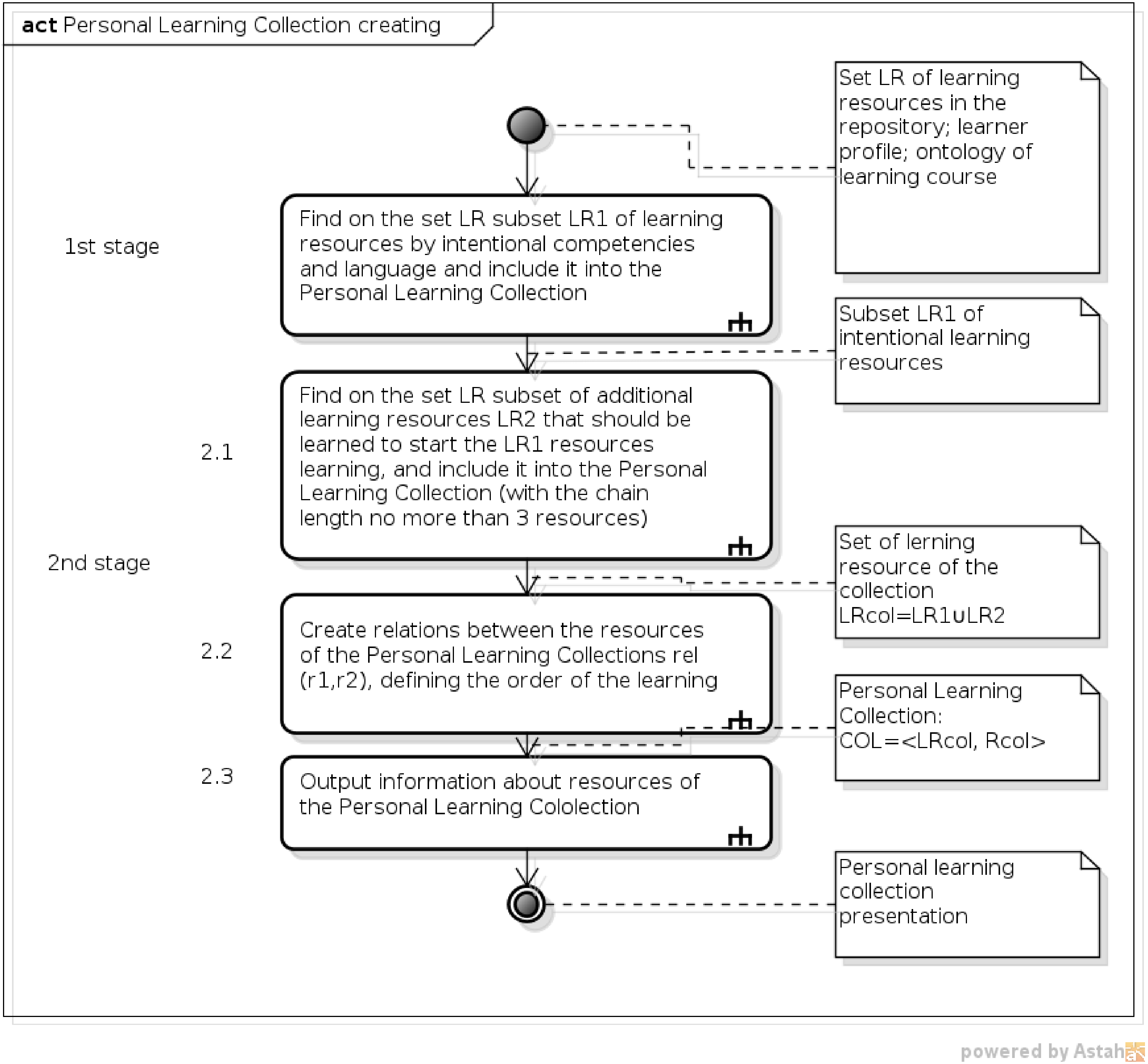
1. Define subnet O_R which is relevant to search query Q and includes the set of resources LR_1 (instances of class C_{ELR1}).

2. For the learning resources with input competences c_i defined by relations $r_{ELR1}(ER, c_i)$ which do not belong to the set of current competences of the learner $\{i_{Qq}, i_{Qr}\}$, redefine subnet O_R: add learning resources with outcome competences c_i and define the following relations – $r_{COL2}(COL, ER)$, where COL – instance of class C_{COL2}, ER – instance of class C_{ELR1} belonging to net O_R; relations $r_{COL3}(ER_i, ER_j)$ which define the sequence of learning.

III. Ontology-based Method for Electronic Learning Resources Retrieval & Integration

1st stage: search for subnet O_R relevant to search query Q. The search is performed using inference engine on the base of semantic rules defined in the ontology as a set of Horn clauses. To implement this stage the semantic rules were formulated for parametrized search on the following parameters: preferred language; outcome learner competencies; mastering level of competences; synonymy of the terms in subject domain.

2nd stage: redefining subnet O_R. To implement this stage the semantic rules were formulated to search the additional resources on the base of current learner competencies, and search the auxiliary resources, as well as the rules for defining the logical links between learning resources in personal collection. Auxiliary resources are the resources which are not included in the set of additional resources because of too long learning sequence but these resources can help to get the missing competences which are not provided by the set of additional resources.



act Personal Learning Collection creating
Set LR of learning resources in the repository; learner profile; ontology of learning course
1st stage
Find on the set LR subset LR1 of learning resources by intentional competencies and language and include it into the Personal Learning Collection
Subset LR1 of intentional learning resources
2.1
Find on the set LR subset of additional learning resources LR2 that should be learned to start the LR1 resources learning, and include it into the Personal Learning Collection (with the chain length no more than 3 resources)
2nd stage
Set of lerning resource of the collection LRcol=LR1∪LR2
2.2
Create relations between the resources of the Personal Learning Collections rel (r1,r2), defining the order of the learning
Personal Learning Collection: COL=<LRcol, Rcol>
2.3
Output information about resources of the Personal Learning Cololection
Personal learning collection presentation
powered by Astah

Ontology Reasoning Rules for Parametric Search of the Learning Resources

The SWRL-rule for learning resources retrieval based on the preferred language and learning resources has the following form:

COL : hasStudent(?c, ?u) ∧ L : hasLanguage(?u, ?l)∧
∧ ELR : hasLanguage(?r, ?l) → COL : hasResourceByLanguage(?c, ?r),
where ?c, ?u, ?l, ?r – SWRL variables,
COL : hasStudent, L : hasLanguage, ELR : hasLanguage,
COL : hasResourceByLanguage — ontology relations with ontology prefixes.

The SWRL-rule for learning resources retrieval based on the outcome competencies and resolving the synonymy problem has the form:

COL : hasStudent(?c, ?u) ∧ L : hasIntentionalDataDomain(?u, ?d)∧
∧DD : hasCompetence(?d, ?cmp1)∧ELR : hasOutputCompetence(?r, ?cmp2)∧
∧ DD : is(?cmp2, ?cmp) ∧ DD : is(?cmp1, ?cmp) →
→ COL : hasResourceByIntentionalcompetencies(?c, ?r).

Ontology Reasoning Rules for the Learning Resources Retrieval Based on the Target Knowledge Field of the Learner

The SWRL-rules for learning resources retrieval based on the target knowledge field of the learner:

COL : hasStudent(?c, ?u)∧
∧ COL : hasResourceByIntentionalcompetencies(?c, ?r)∧
∧ L : hasIntentionalDataDomain(?u, ?d) ∧ DD : hasCompetence(?d, ?cmp1)∧
∧ ELR : hasOutputCompetence(?r, ?cmp2) ∧ DD : is(?cmp2, ?cmp)∧
∧ DD : is(?cmp1, ?cmp) ∧ L : hasIntentionalComplexity(?cmp1, ?level)∧
∧ ELR : hasOutputComplexity(?cmp2, ?level) →
→ COL : hasResourceByOutputDomain(?c, ?r).

- Additional SWRL rules defined similarly to the rules above

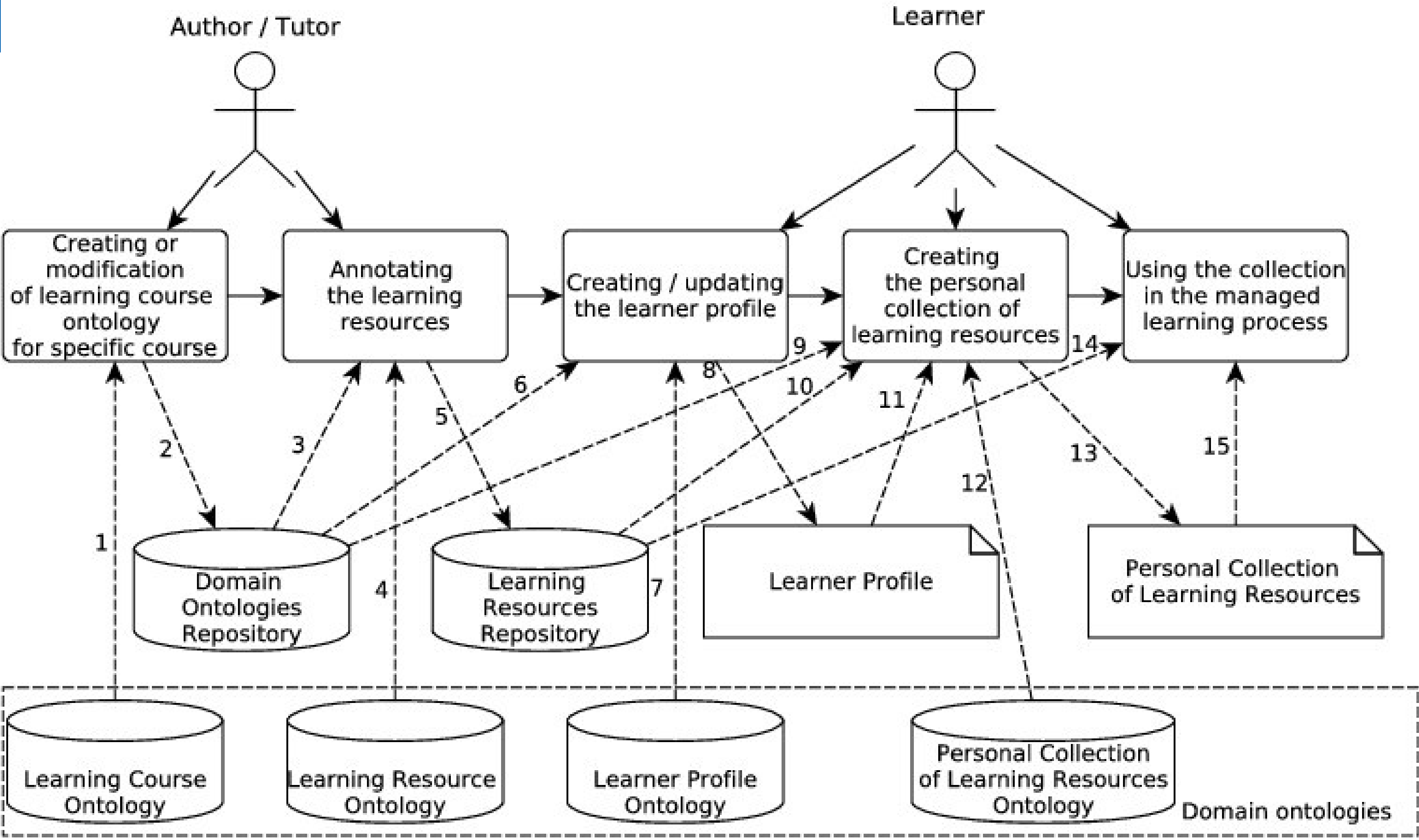
- Algorithm for additional learning resources retrieval based on the current knowledge field of the learner described

Rules for Creating the Personal Collection of Learning Resources

The personal collection of learning resources is the sets R_0 and R_1 (defined with relation COL : hasResource) of learning resources and the set R_2 of auxiliary learning resources with logical relations between the resources defined with the rule:

COL : hasResource(?c, ?r1) ∧ COL:hasResource(?c, ?r2)∧
∧ ELR:hasOutputCompetence(?r1, ?cmp1)∧
∧ ELR:hasInputCompetence(?r2, ?cmp2) ∧ DD:is(?cmp1, ?cmp)∧
∧ DD:is(?cmp2, ?cmp) → COL:hasNextResource(?r1, ?r2).

Ontology-based approach to creation of personal learning collections



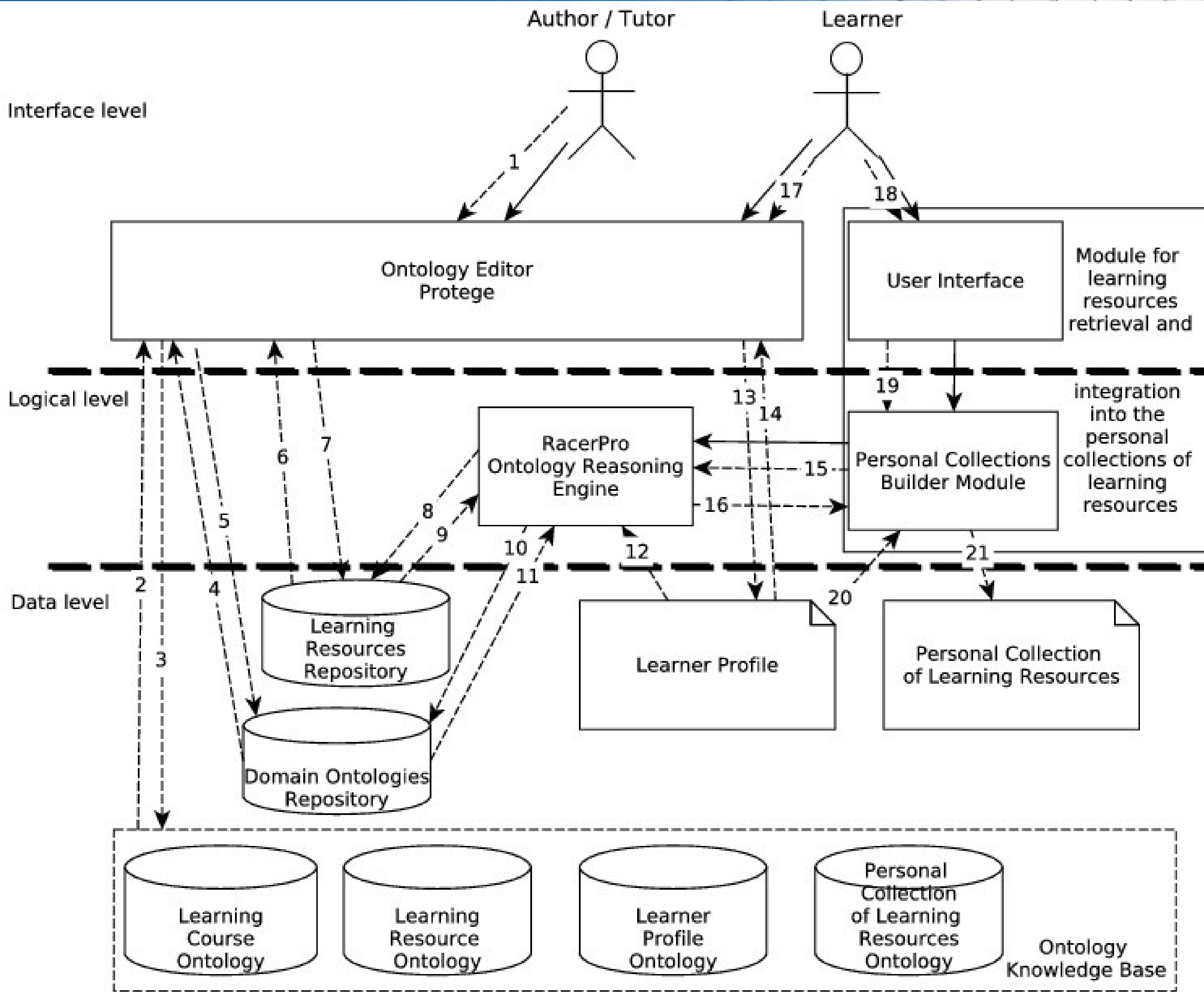
Personal Collection Quality Assessment

Precision: $p = \frac{\left|RL'_{COL}\right|}{\left|RL'_{COL}\right| + \left|RL''_{COL}\right|}$,

Recall: $r = \frac{\left|RL'_{COL}\right|}{\left|RL'\right|}$,

F-measure: $F = \frac{2}{\frac{1}{p} + \frac{1}{r}}$,

where RL'_{COL} - relevant resources of the collection, RL''_{COL} - irrelevant resources of the collection, RL' - relevant resources in the repository, RL'' - irrelevant resources in the repository, RL - resources in the repository, RL_{COL} - resources of the collection, $RL' \bigcup RL'' = RL$, $RL'_{COL} \bigcup RL''_{COL} = RL_{COL}$.



Author / Tutor
Learner
Interface level
Logical level
Data level
1
17
18
Ontology Editor
Protege
User Interface
Module for learning resources retrieval and integration into the personal collections of learning resources
19
13
14
6
7
5
RacerPro
Ontology Reasoning
Engine
15
16
Personal Collections
Builder Module
8
9
10
11
12
21
20
2
4
3
Learning
Resources
Repository
Domain Ontologies
Repository
Learner Profile
Personal Collection
of Learning Resources
Learning
Course
Ontology
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Learner
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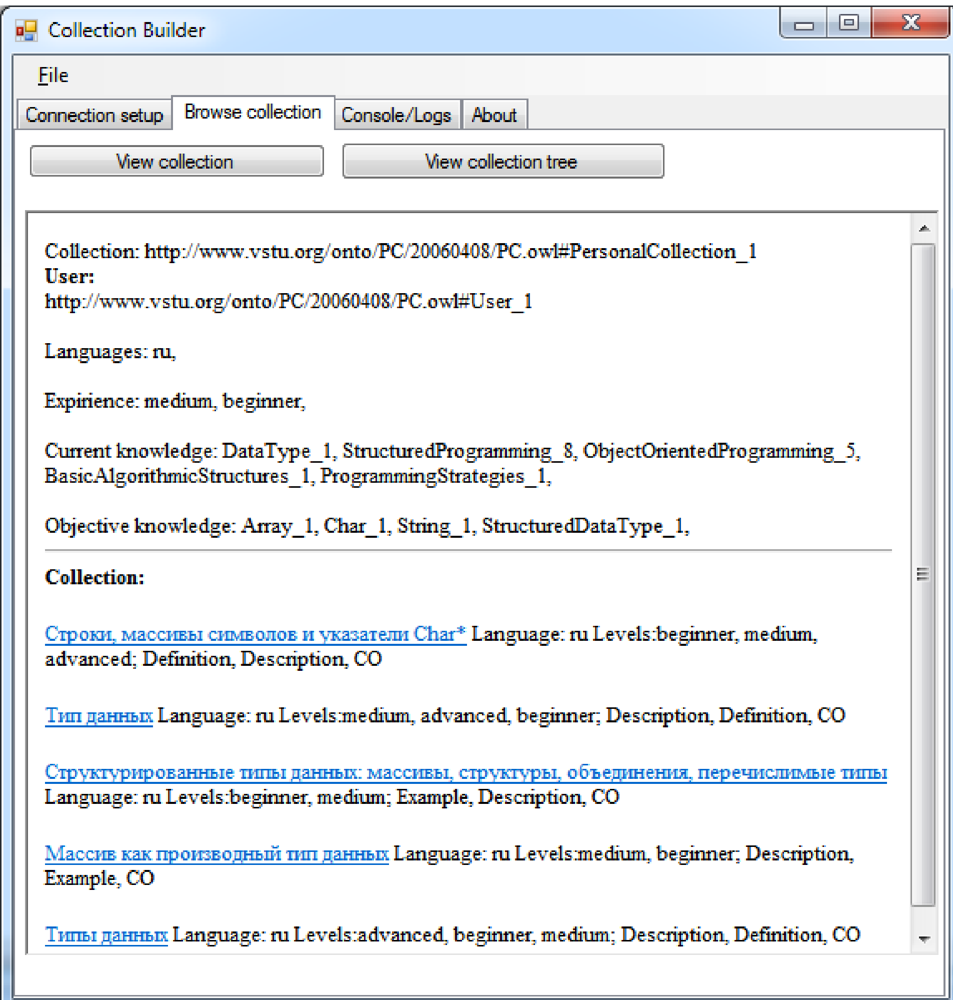
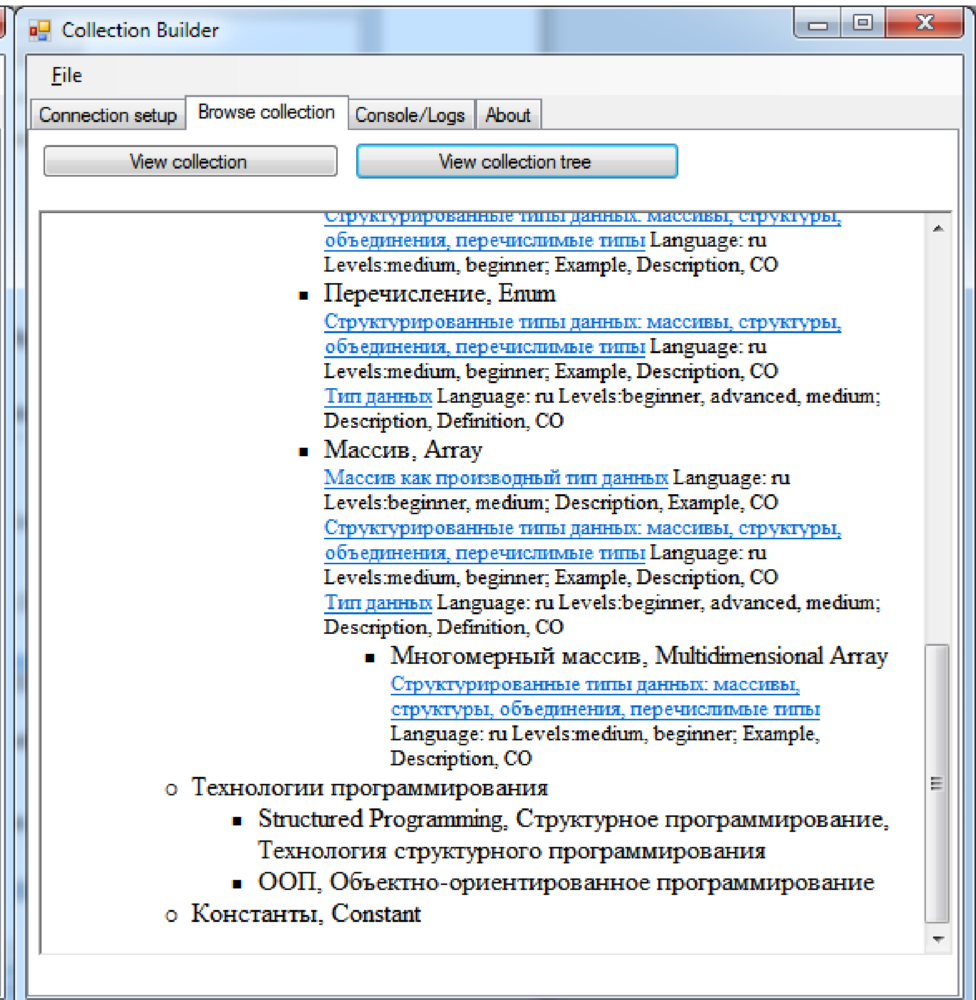
Resources
Ontology
Ontology
Knowledge Base

Personal Collection Builder





Personal Collection Quality Assessment Results

1) the average time of collection creation decreased almost by 99%;
2) automatically generated collection contains 100% of learning resources obtained by the intersection of the collections created by tutors for each student, and 91% of learning resources obtained by combining the tutors collections;
3) the average value of collection recall increased by 29%, precision - by 2,9%, F-measure - by 16,3% in comparison with non-automated process.

Conclusion

- The concept of learning management in the open learning network was proposed on the base of learning resources retrieval and creating the personal learning collections using ontology-based approach.

- The ontological model for knowledge representation was developed including ontologies of learning course domain, learning resource, learner's profile and personal learning collection. The last one includes the ontology reasoning rules for creating the personal learning collection.
Also the algorithm for additional learning resources retrieval was proposed.

- The software architecture and tool for creating the personal learning collections were designed and implemented within framework of proposed knowledge-based approach with employment of the object-oriented analysis and C# language.

Further Work

- Developing the software tools for creating the learning course ontologies and annotating the learning resources

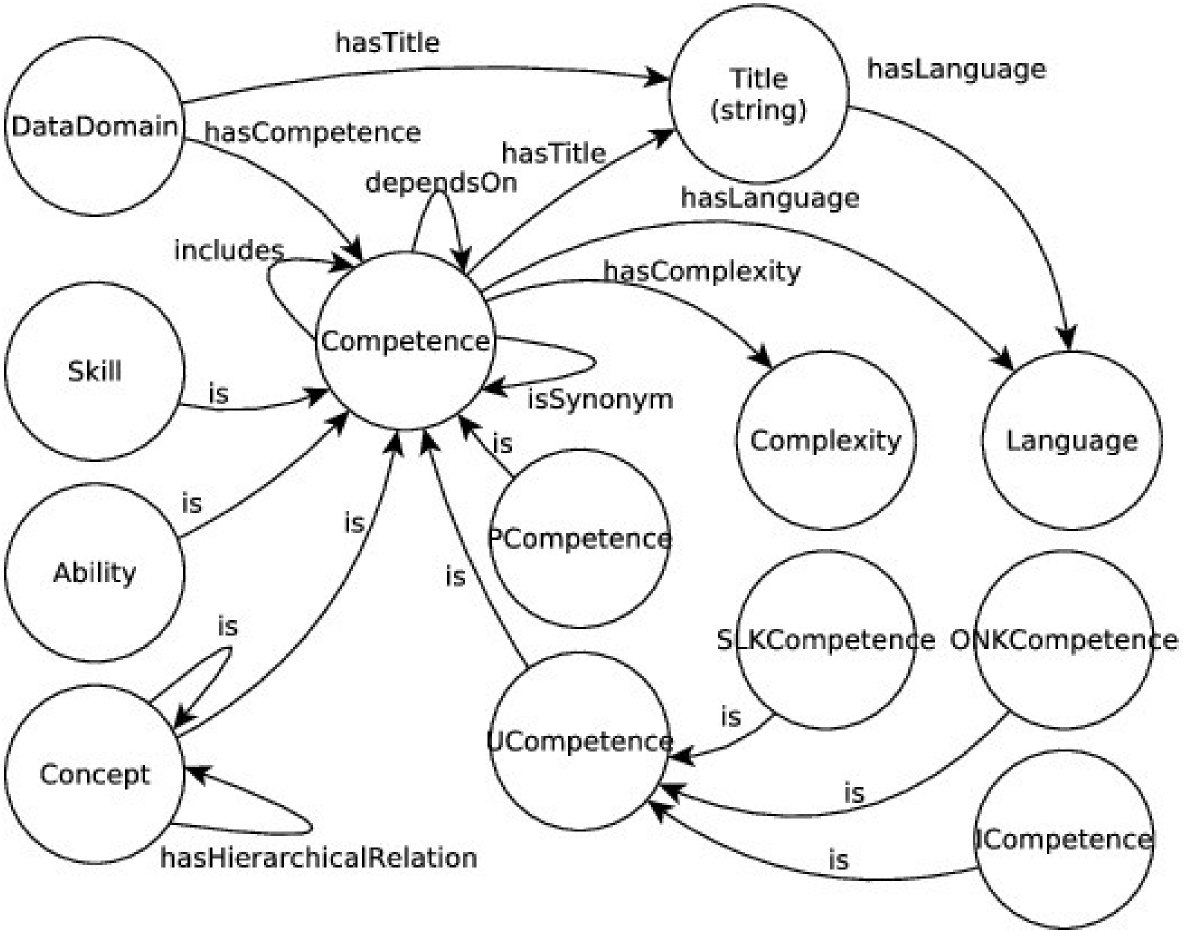
- Developing the ontologies for other university courses

- Filling up the repository of learning resources

- Integration with LMS Moodle

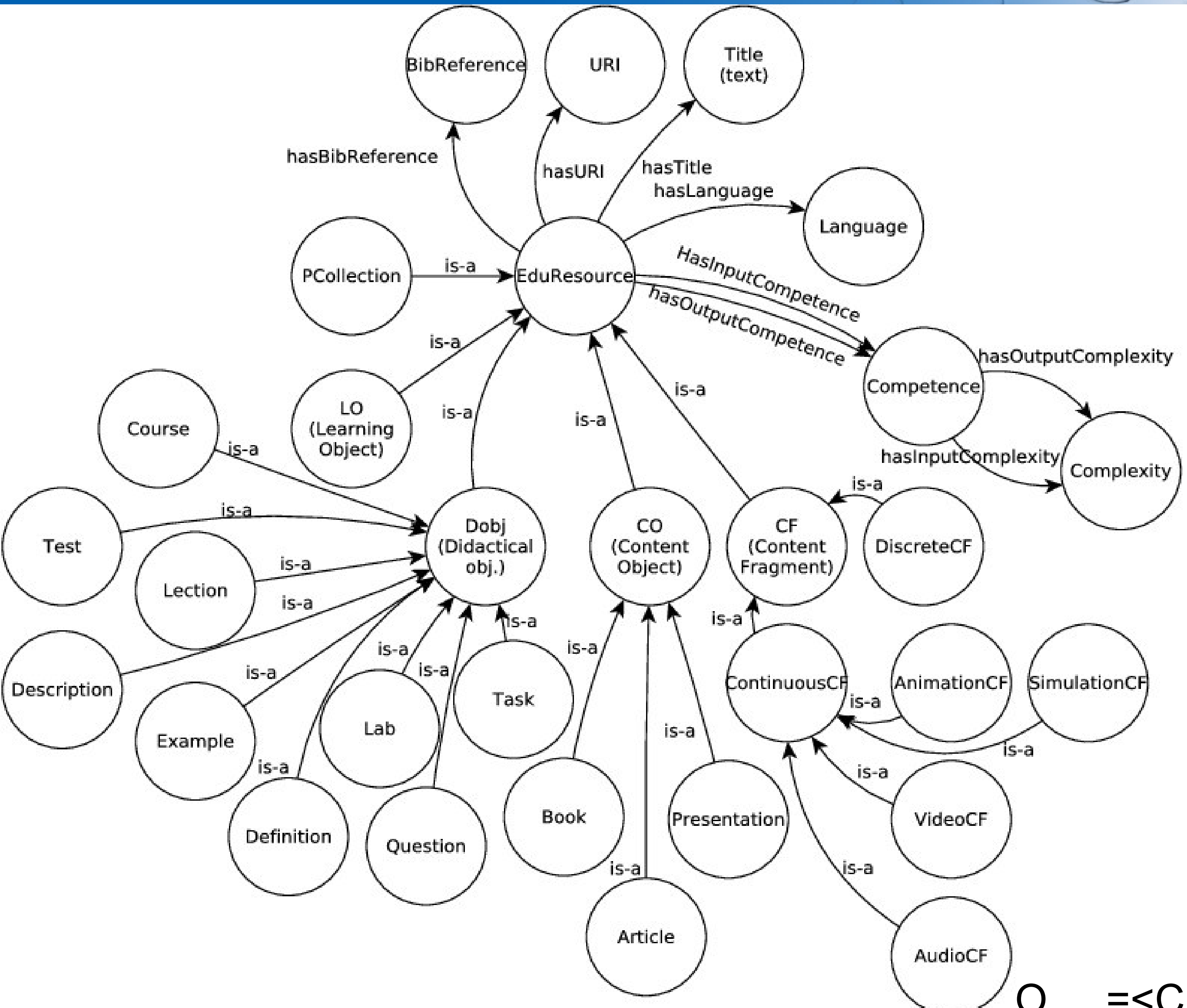
¿Questions?

Learning course domain ontology



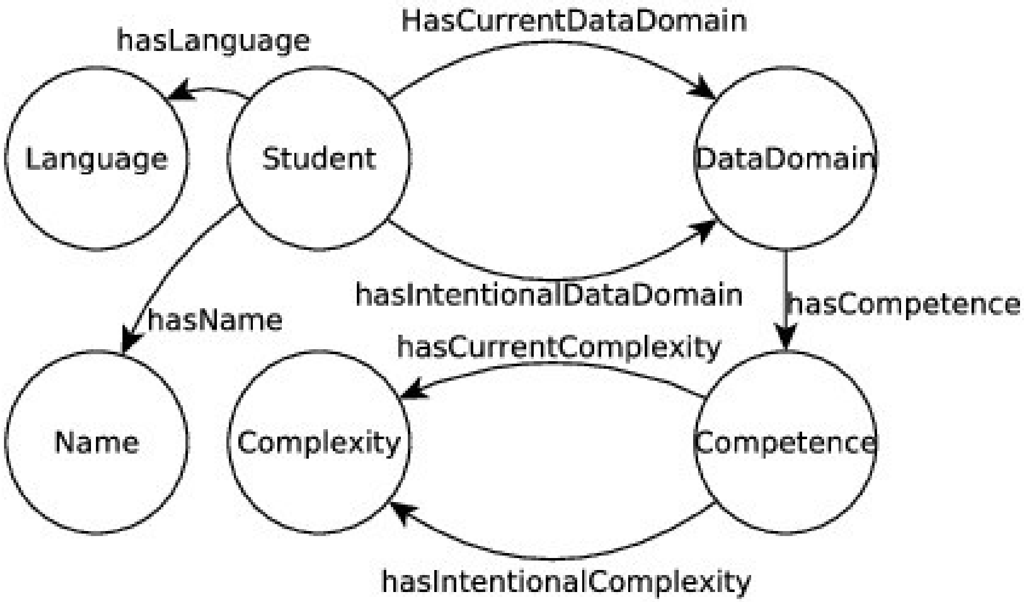
$$O_{DD} =< C_{DD}, Inst_{DD}, R_{DD}, I_{DD}>$$

Learning resource ontology (fragment)



$O_{ELR} =<C_{ELR}, Inst_{ELR}, R_{ELR}, I_{ELR}>$

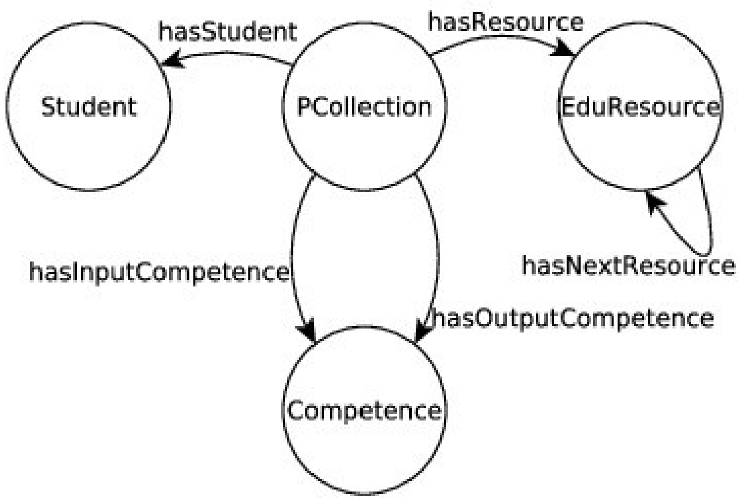
Learner profile ontology



$O_L = \langle C_L, Inst_L, R_L, I_L \rangle$,

where C_L — finite set of concepts of Learner profile ontology;
$Inst_L$ — set of exemplars of classes C_L of the Learner profile ontology;
R_L — finite set of relations of Learner profile ontology;
$I_L = \varnothing$.

Personal learning collection ontology



$O_{COL} =< C_{COL}, Inst_{COL}, R_{COL}, I_{COL} >$,

where C_{COL} — finite set of concepts of Personal learning collection ontology;
$Inst_{COL}$ — set of exemplars of classes C_{COL} including created personal collections that can be stored in the repository of personal collections;
R_{COL} — finite set of relations of Personal learning collection ontology;
I_{COL} — finite set of reasoning rules for creating the collection.