Ontology-based Learning Content Management System in Programming Languages Domain

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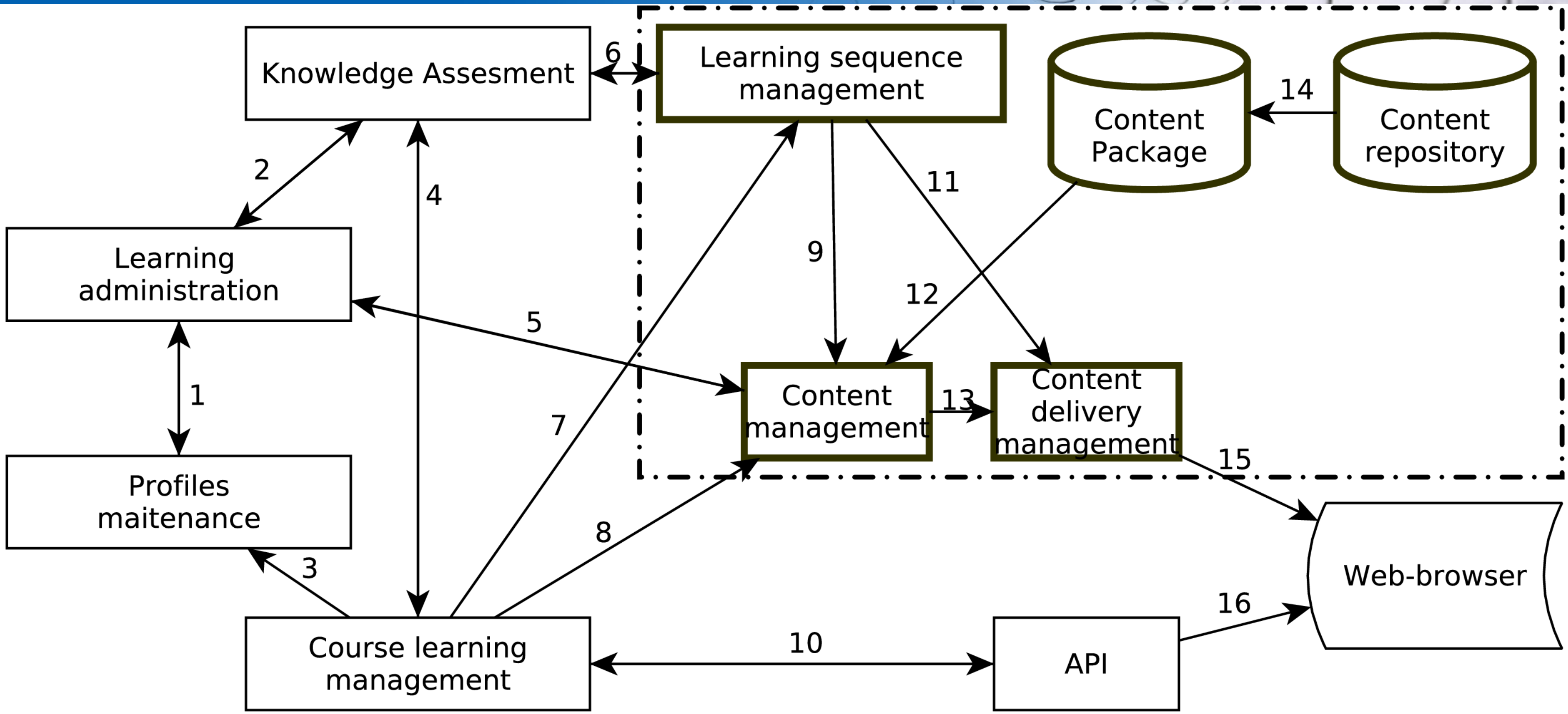
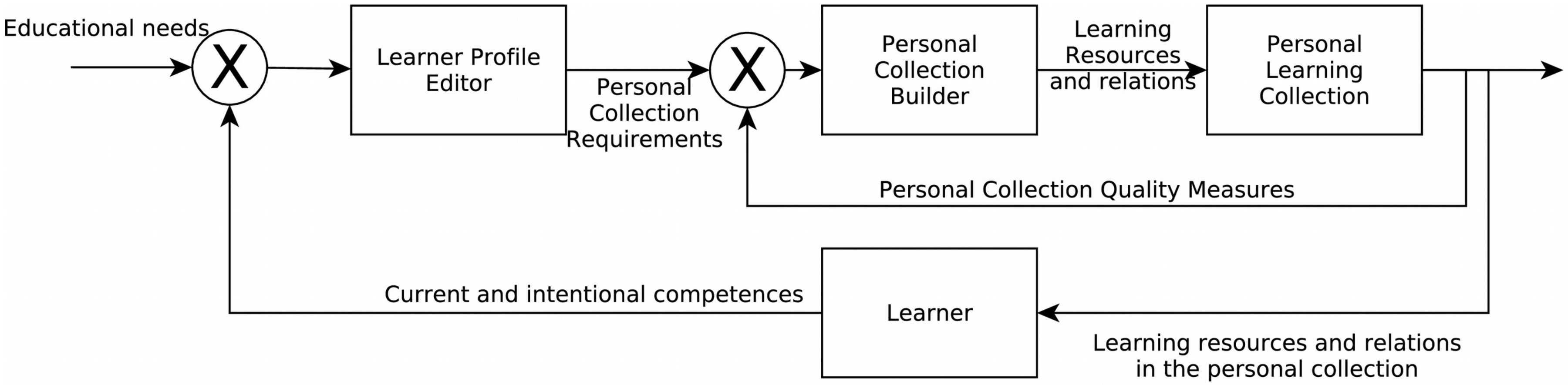
Modern Learning Management Systems Architecture



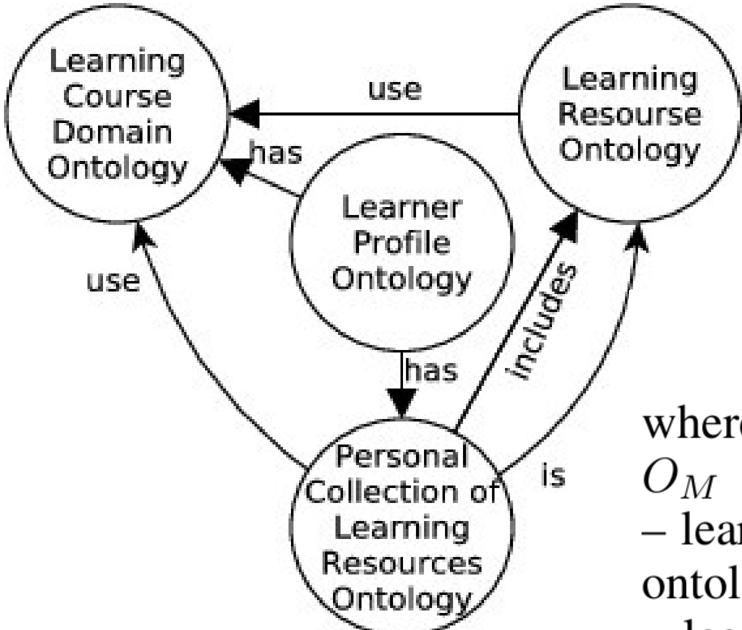
1 - base information about LMS users; 2 - learning achievement reports, tests planning; 3 - learning course achievements; 4- current learning course achievements for modules of the course, modules tests results; 5 - learning content administration; 6 - testing results (for modules of the course); 7 - information about learning sequence of modules of the course; 8 - content selection for the learning course; 9 - content request; 10 - course learning management using the API (with third-party software); 11 - managing the content representation for the learner; 12 - content package; 13 - selected learning content; 14 - results of content selection from the content repository; 15 - representation of the learning content for learner; 16 - interactions using API with HTTP-requests.

Learning content management as a control system



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



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

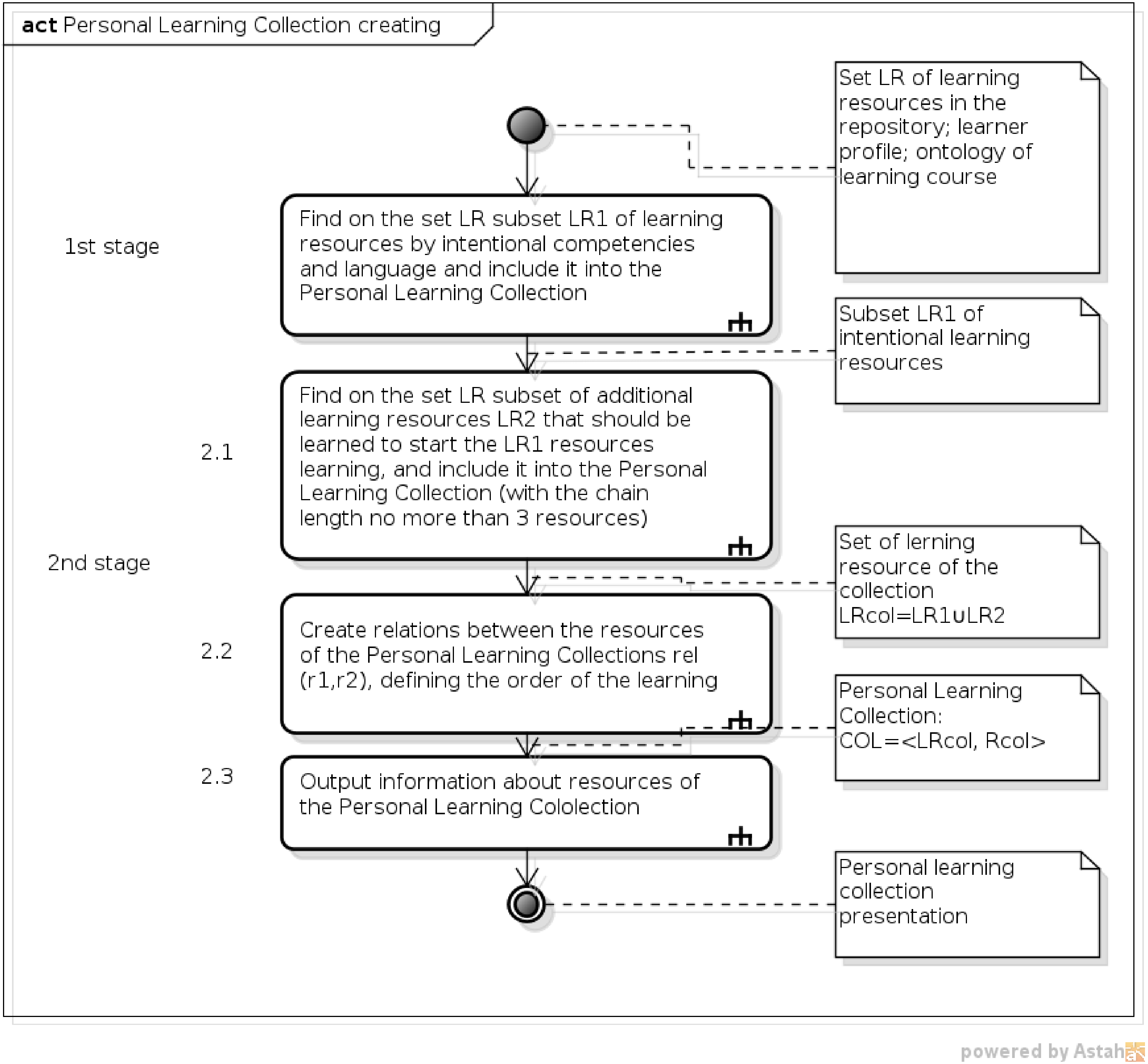
where M – meta-ontology;
$O_M = \{O_{DD}, O_{ELR}, O_{COL}, O_L\}$ – set of ontologies, O_{DD} – learning course domain ontology, O_{ELR} – learning resource ontology, O_{COL} – personal learning collection ontology, O_L – learner profile ontology;
C – finite set of meta-ontology concepts, $C = \varnothing$;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

Ontology-based Method for Electronic Learning Resources Retrieval & Integration (1/2)

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.

Ontology-based Method for Electronic Learning Resources Retrieval & Integration (2/2)

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:

$$\begin{aligned}
&COL : hasStudent(?c, ?u) \wedge \\
&\wedge\ COL : hasResourceByIntentionalcompetencies(?c, ?r) \wedge \\
&\wedge\ L : hasIntentionalDataDomain(?u, ?d)\ \wedge\ DD : hasCompetence(?d, ?cmp1) \wedge \\
&\wedge\ ELR : hasOutputCompetence(?r, ?cmp2)\ \wedge\ DD : is(?cmp2, ?cmp) \wedge \\
&\wedge\ DD : is(?cmp1, ?cmp)\ \wedge\ L : hasIntentionalComplexity(?cmp1, ?level) \wedge \\
&\wedge\ ELR : hasOutputComplexity(?cmp2, ?level) \rightarrow \\
&\rightarrow COL : hasResourceByOutputDomain(?c, ?r).
\end{aligned}$$

- Additional SWRL rules defined similarly to the rules above

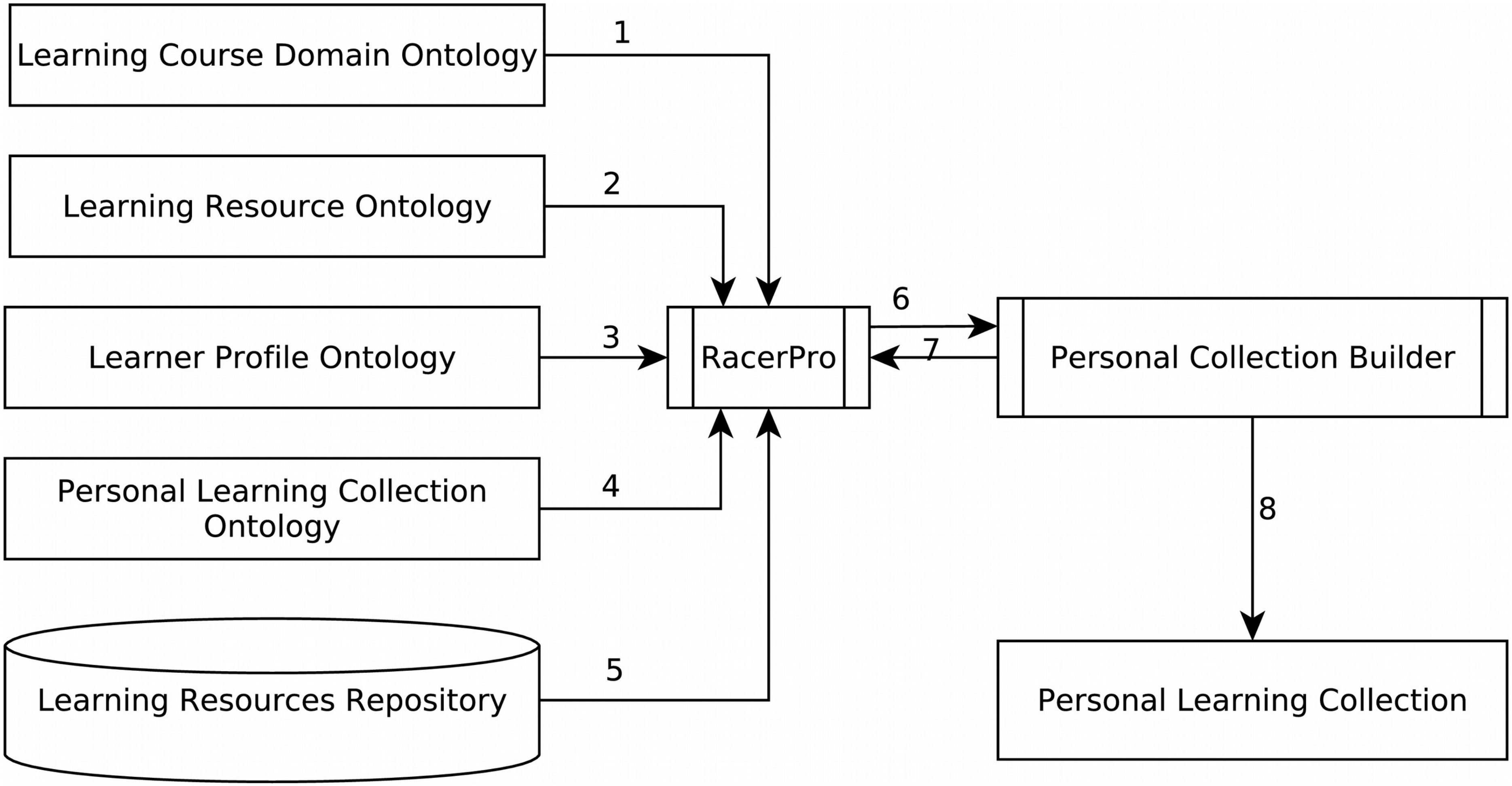
- Algorithm for additional learning resources retrieval based on the current knowledge field of the learner described

Rules for Creating the Personal Collection of Learning Resources

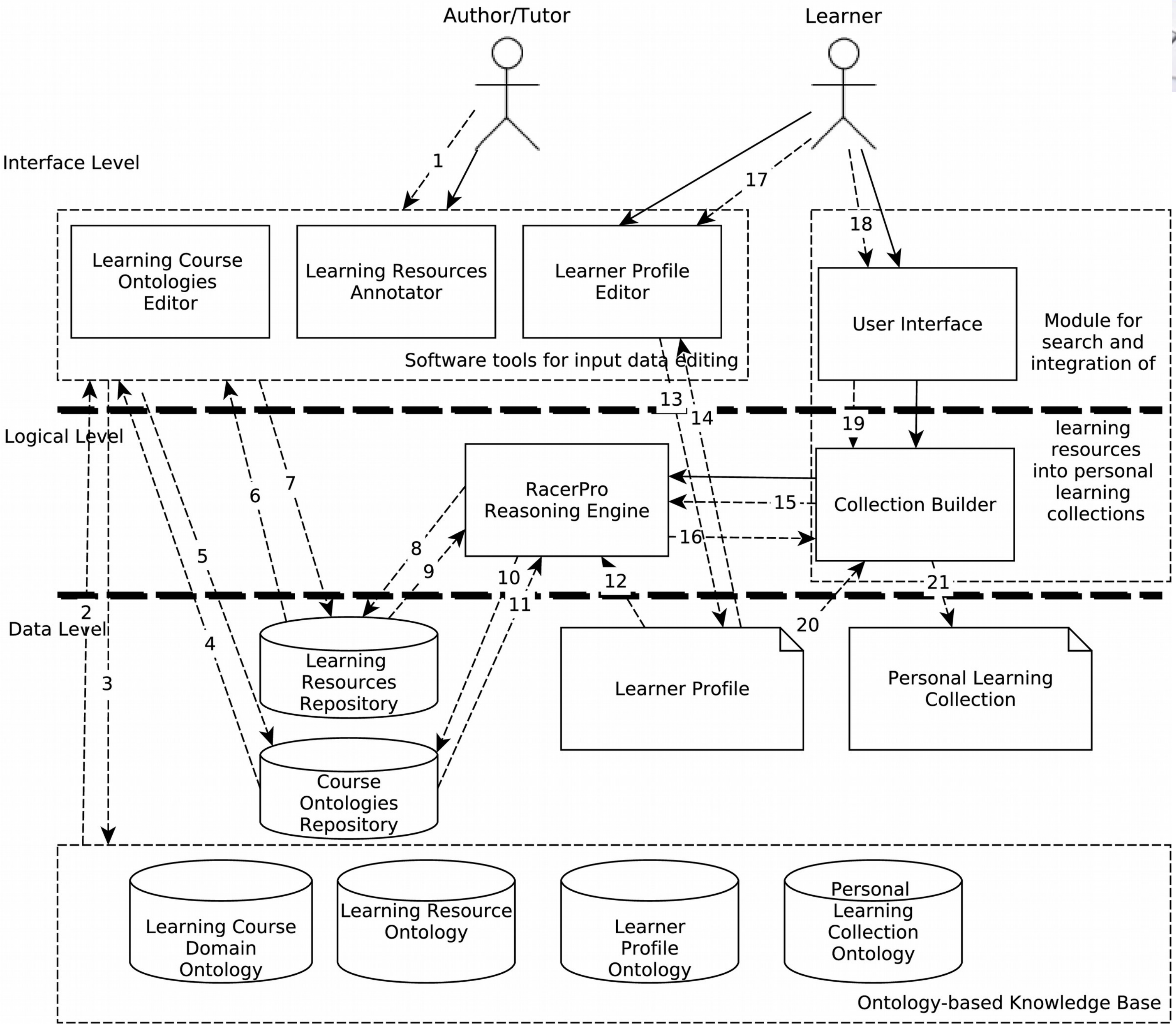
The personal collection of learning resources is the sets R_0 and R_1 (defined with relation COL : hasResource) of learning resources and the set R_2 of auxiliary learning resources with logical relations between the resources defined with the rule:

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).

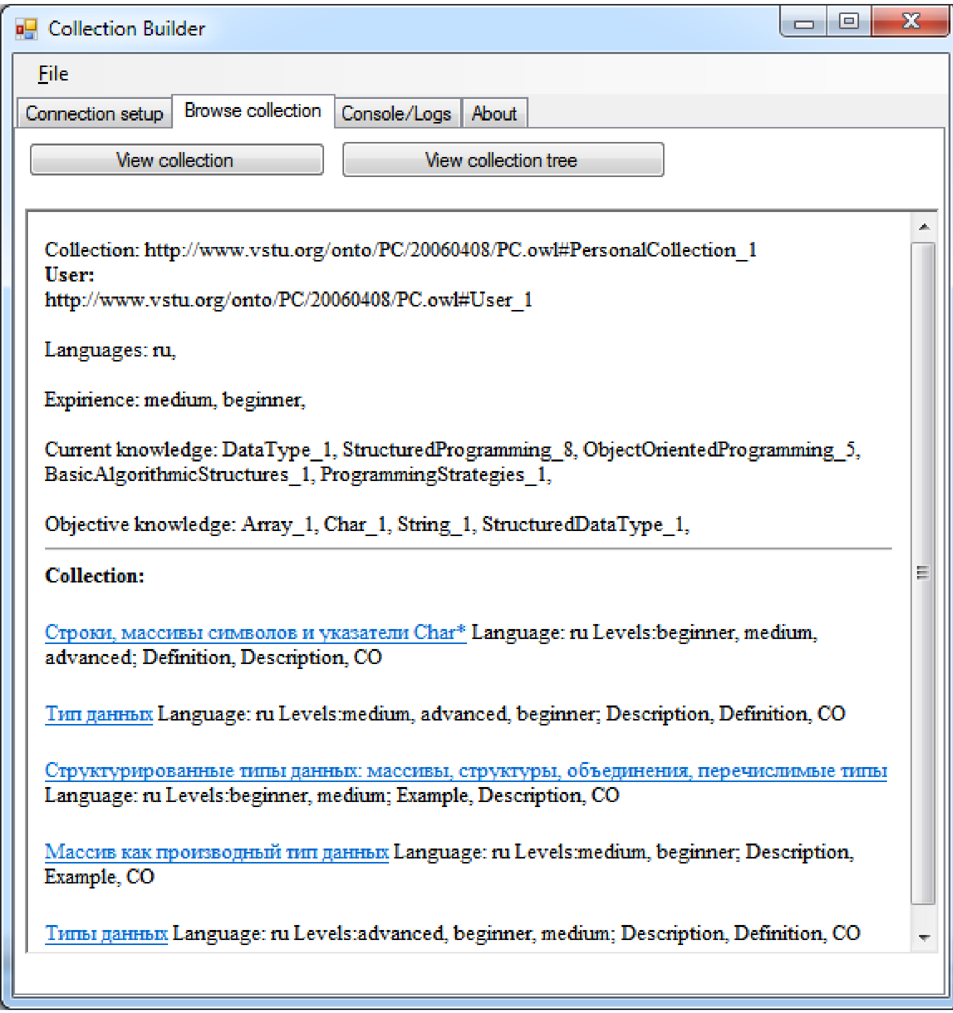
Framework for integration of the ontologies and RacerPro reasoning engine to create the personal learning collections

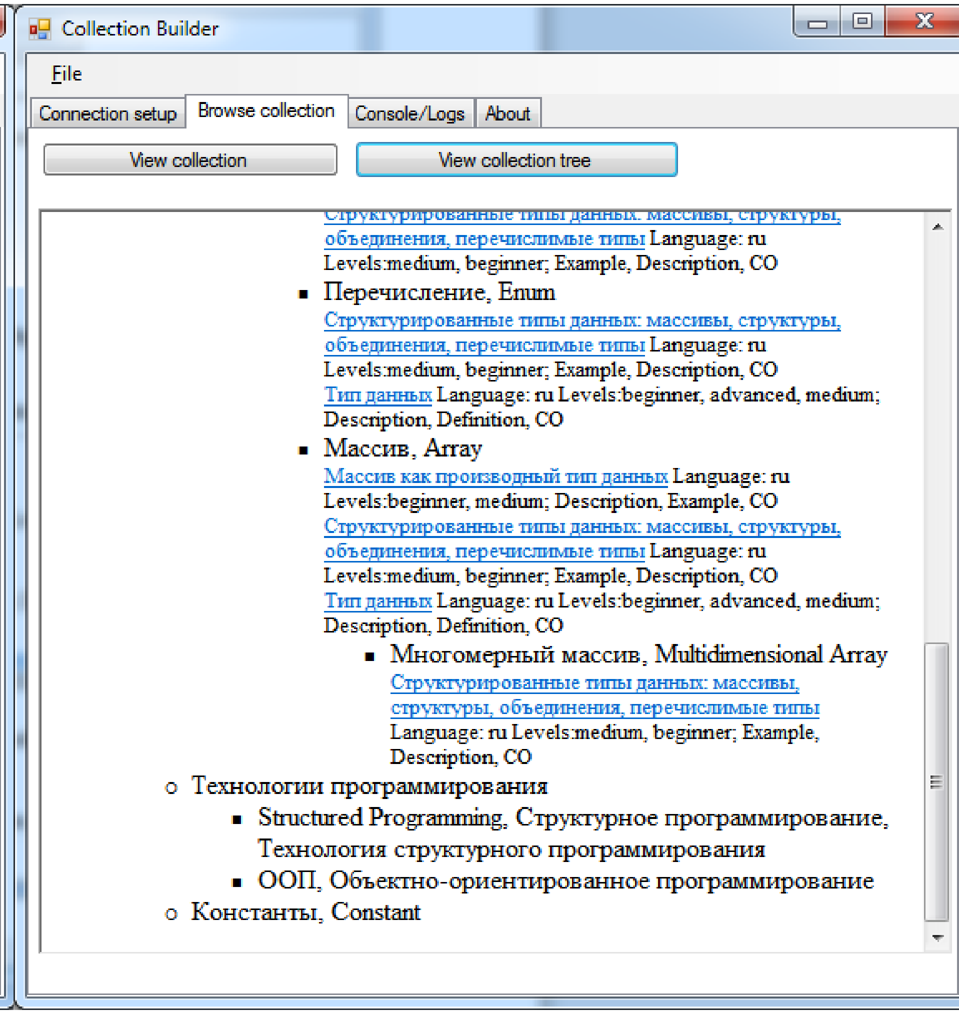


Software architecture of LCMS



Personal Collection Builder





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, $RL' \bigcup RL'' = RL$, $RL'_{COL} \bigcup RL''_{COL} = RL_{COL}$.

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 architecture of LCMS and special software tool for creating the smart learning content in form of personal learning collections were designed and implemented within framework of proposed ontology-based approach in the domain of programming languages.

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 set of semantic rules for creating the personal learning collection.

The new two-stage method for electronic learning resources retrieval and integration into personal learning collection was developed based on ontology reasoning rules.

Further Work

- reimplementation of the collection builder as a web application using the Stardog Enterprise Graph Database as a data store and reasoning engine;

- implementation the software tool as a web application for creating the learning course ontologies;

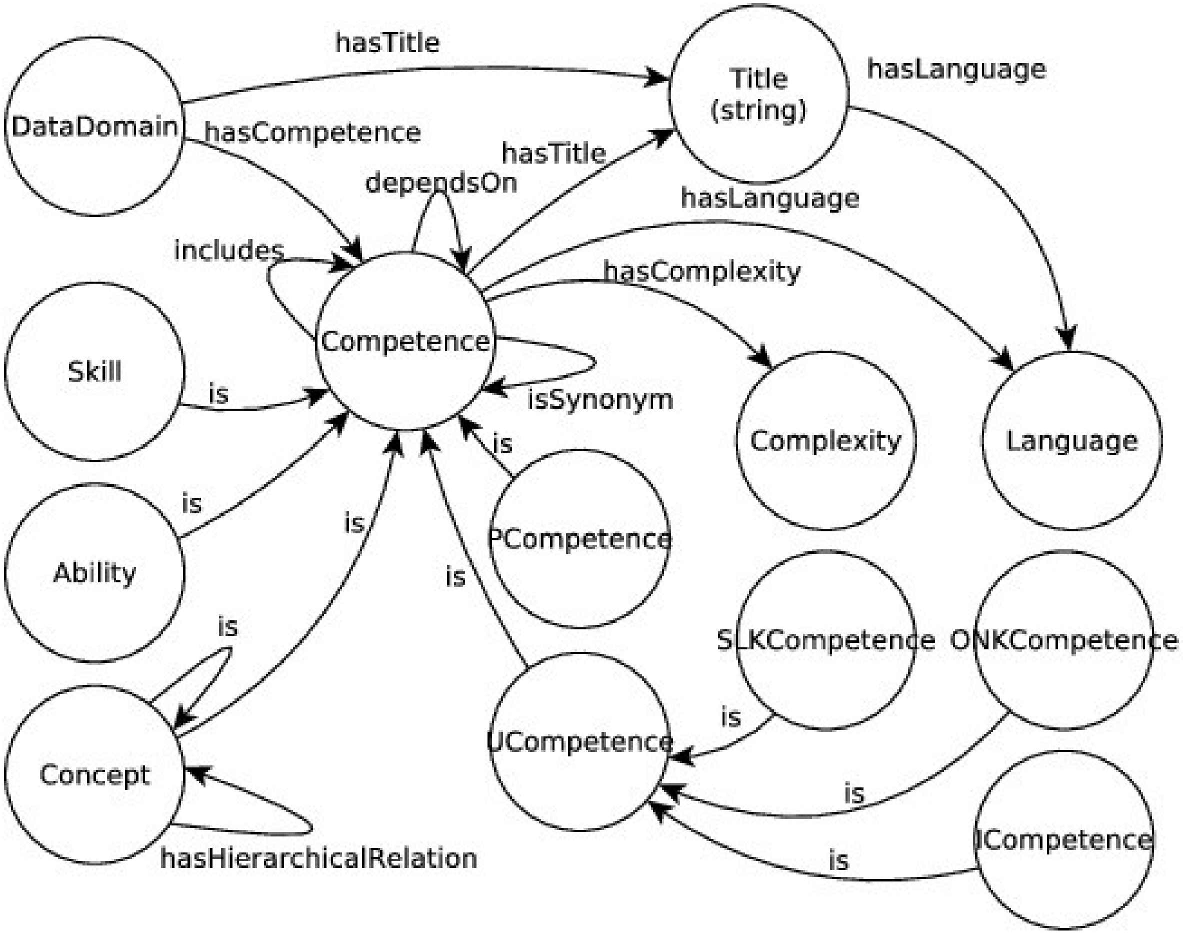
- developing software tool as a web application for annotating the learning resources;

- developing ontologies for other university courses;

- the learning resources repository (with Stardog backend as a data store) should be further scaled for subject domain of software engineering to provide the creation of personal collections for variety of learning courses.

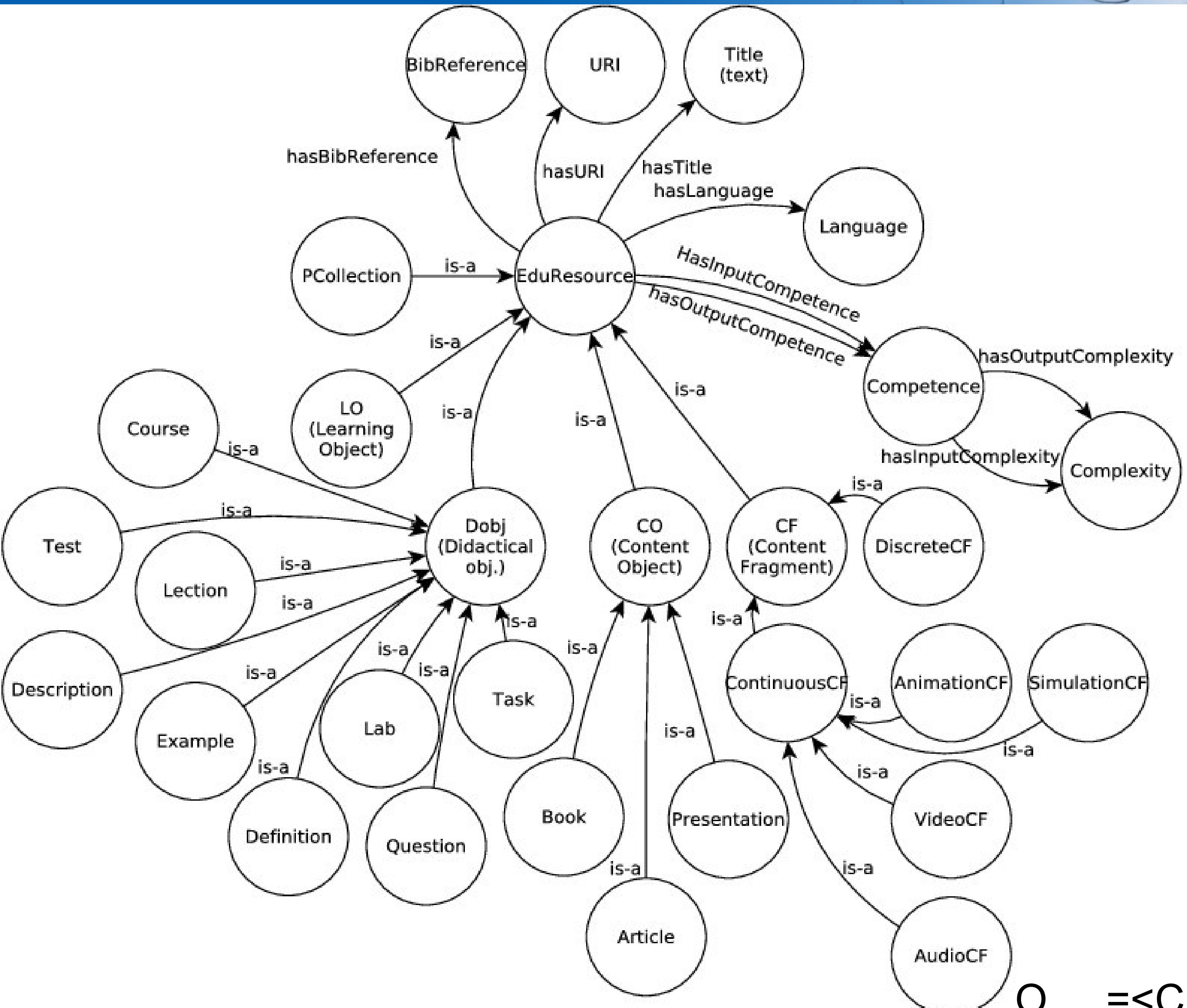
¿Questions?

Learning course domain ontology



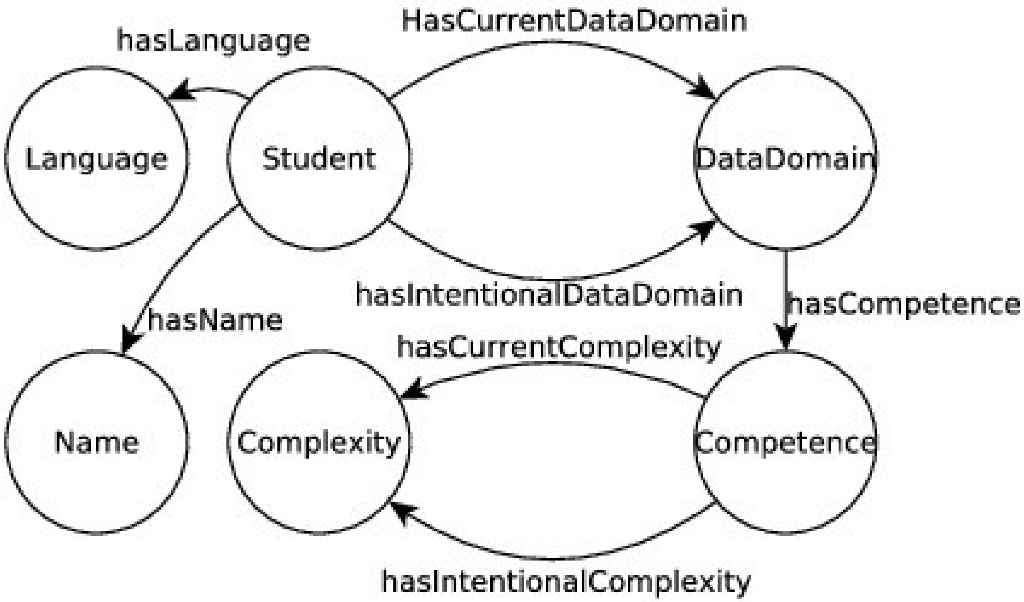
$$O_{DD} = < C_{DD}\ , Inst_{DD}\ , R_{DD}\ , I_{DD} >$$

Learning resource ontology (fragment)



$O_{ELR} = \langle C_{ELR}, Inst_{ELR}, R_{ELR}, I_{ELR} \rangle$

Learner profile ontology



$O_L = < C_L , Inst_L , R_L , I_L >$,

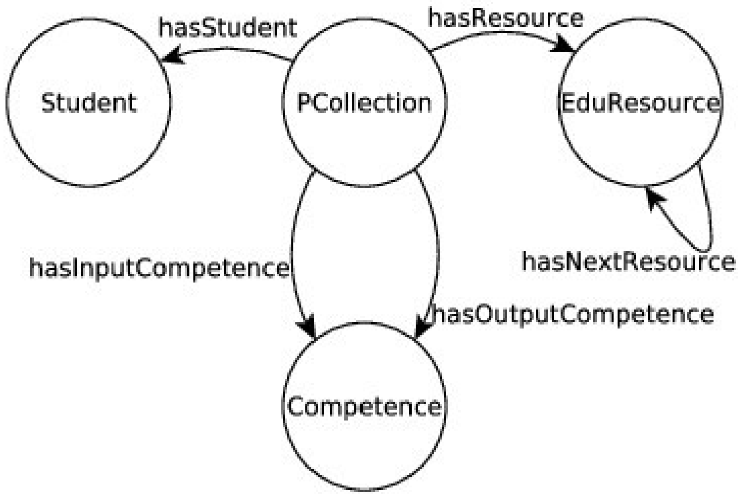
where C_L — finite set of concepts of Learner profile ontology;

$Inst_L$ — set of exemplars of classes C_L of the Learner profile ontology;

R_L — finite set of relations of Learner profile ontology;

$I_L = \varnothing$.

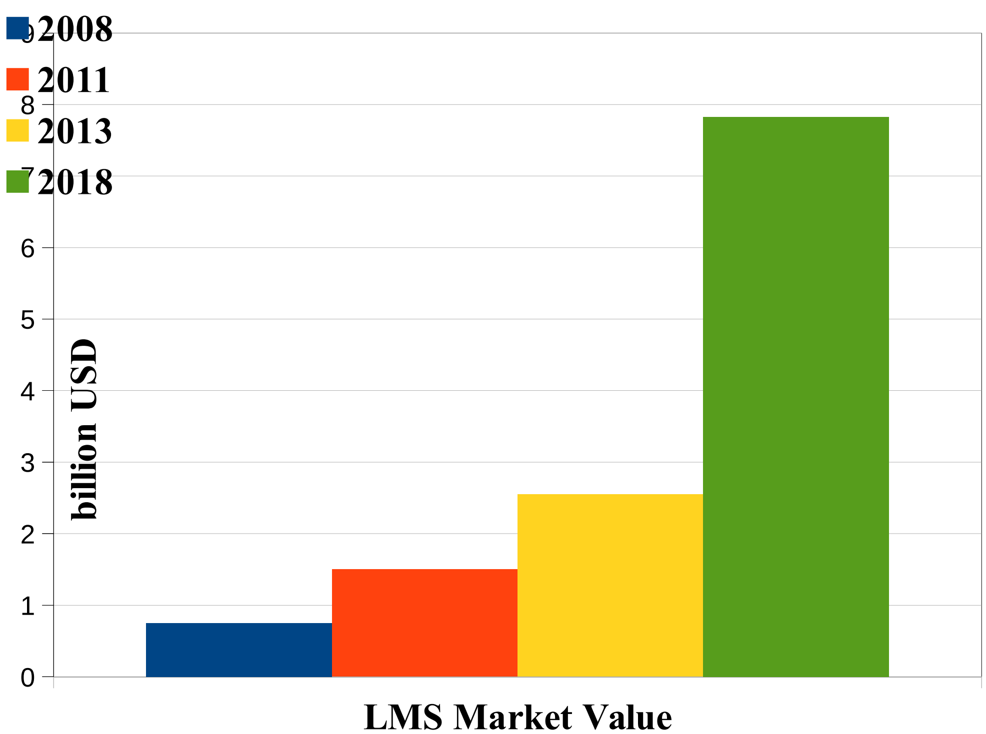
Personal learning collection ontology



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

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.

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