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Ontology-based Collaborative Development of Domain Information Space for Learning and Scientific Research

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Outline

I. Introduction & State of the Art

II. Ontology-based Approach to the Collaborative Development of Domain Information Space

   a. Cognitive and Information space models

   b. The structure of the ontology of cognitive and information spaces

   c. Cognitive and information spaces creating process and scenarios

   d. Cognitive-information space editor

   e. Personal Collection Builder

III. Conclusion

IV. Further Work

Information support of research and learning processes

Information support of research (on the early stages) and learning processes involves thematic information retrieval and has specificities:

(a) in the beginning of the retrieval a person cannot realize clearly his information needs and has only general idea - a topic, so he is not able to create correct search query for the search engine;

(b) during the information retrieval a person redefines his information needs;

(c) according to educational or research goals, person has a particular domain viewpoint.

Thematic information retrieval approaches

Thematic directories and learning resources repositories; OpenCourseWare approach

+ contain resources with high relevance to some domain viewpoint
– the structure is rigid enough and reflects the subject domain viewpoint of some group of experts in some aspect
– creating and updating the collection of the information resources requires a lot of effort

Electronic libraries (ACM Digital Library, IEEE Xplore Digital Library, SpringerLink, ISI Web of Sciences)

+ huge amount of scientific information resources
– the search results can have insufficient relevance to the domain viewpoint as these libraries not support semantic search in the subject domains

Semantic Web

+ allows to describe the domain with different viewpoints
– it is difficult to automate the creation of the domain descriptions with different viewpoints
– it is difficult to estimate the relevance of the information resource to some domain viewpoint automatically

Thematic information retrieval task as Ad-Hoc Object Retrieval task with use of domain viewpoint

INPUT:

(a) keyword query – the query defines one or some domain concepts
(b) query type - «type query": the intention of the query is to find entities of a particular class
(c) query intent - class "information resource"
(d) data graph – the repository of cognitive and information spaces where the objects are the concepts of the domain and the information resources

OUTPUT: a ranked list of information resource identifiers from data graph

+ domain viewpoint is defined by cognitive space
+ information space contains the information resources with high relevance to some domain viewpoint
+ the collaborative annotating the information resources with some domain viewpoint is possible
– creation of the cognitive and information spaces requires a lot of effort
– collaborative creation of the information spaces requires judges merging

Cognitive and Information space models (1/3)

- ✓ A cognitive space is the set of concepts and relations among them held by a human [9, 10]
- ✓ The cognitive space can be individual as well as shared by a group of people

CognitiveSpace = <Concepts, IncludesRelation>, (1)

where:

Concepts - set of the concepts of the subject domain;

IncludesRelation - set of the subsumption relations defined on the set of the concepts.

9. Gregory B. Newby: Cognitive space and information space. In Journal of the American Society for Information Science and Technology, Vol.52, Issue12, pp.1026–1048 (2001)

10. Gregory B. Newby: Metric Multidimensional Information Space. In Proceedings of TREC-5. Gaithersburg, MD: The National Institute of Science and Technology (1996)

Cognitive and Information space models (2/3)

- ✓ An information space is the set of objects and relations among them held by information system [9, 10]
- ✓ The information space should be consistent with the cognitive space of particular human or group of people

InformationSpace = <Objects, Relations, Rules>, (2)

where:

Objects - set of the objects of the subject domain held by the information system,

Relations - set of the relations between these objects,

Rules - set of the reasoning rules for setting the relations between the objects.

9. Gregory B. Newby: Cognitive space and information space. In Journal of the American Society for Information Science and Technology, Vol.52, Issue12, pp.1026–1048 (2001)

10. Gregory B. Newby: Metric Multidimensional Information Space. In Proceedings of TREC-5. Gaithersburg, MD: The National Institute of Science and Technology (1996)

Cognitive and Information space models (3/3)

Objects = <Concepts, InformationResources>, (3)
where:
Concepts - set of the concepts of the subject domain;
InformationResources - set of the information resources associated with the concepts of the subject domain.

Relations = <ConceptRepresentationRelations, IRRelations>, (4)
where:
ConceptRepresentationRelations - set of the association relations between the concepts of the subject domain and information resources:

$$Concepts \times InformationResources \rightarrow \{undefined, bad, good, excellent\}, \quad (5)$$

where: excellent - the resource describes the concept in full; bad - the resource contains minimal information about the concept; good - intermediate value between the excellent and bad; undefined - the resource describes the concept with relevance which is not defined yet;

IRRelations - set of the relations between the information resources.

Tasks for information retrieval using the information space

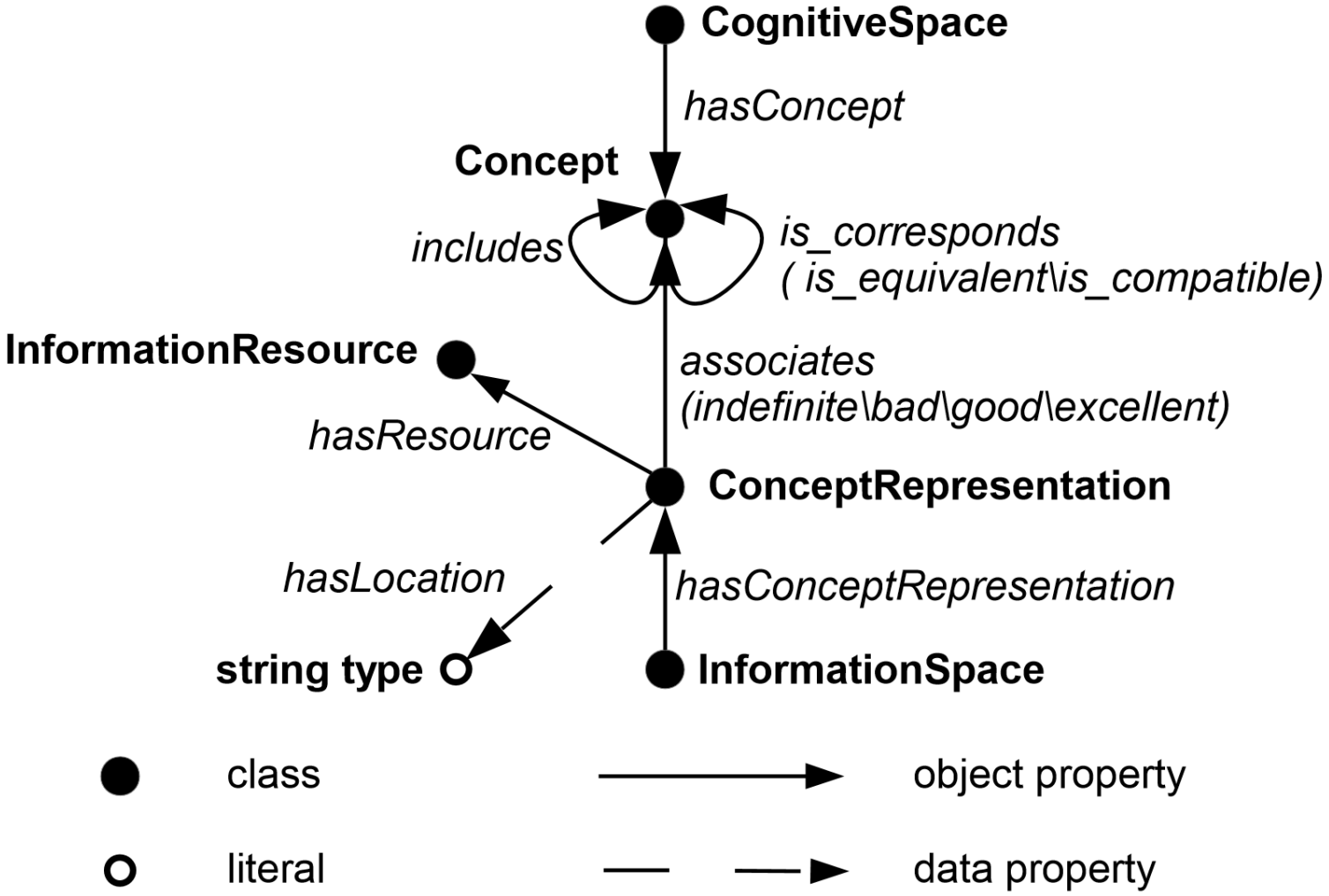
1) **The cognitive and information spaces creating**

2) The information space retrieval from the repository

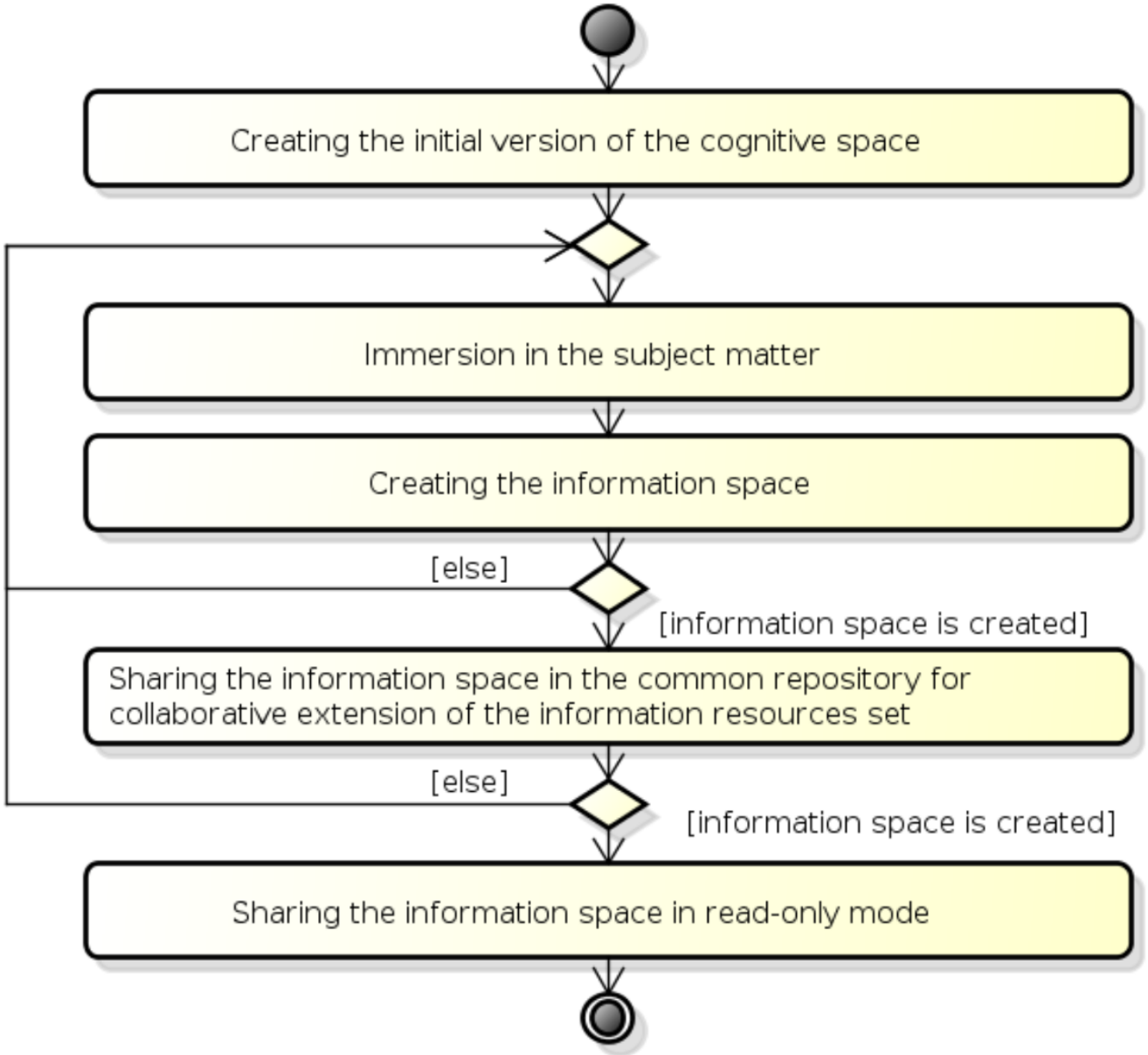
3) The concept retrieval from the information space

4) The information space navigation to define more exactly the search query and the information needs

The structure of the ontology of cognitive and information spaces



Cognitive and information spaces creating process



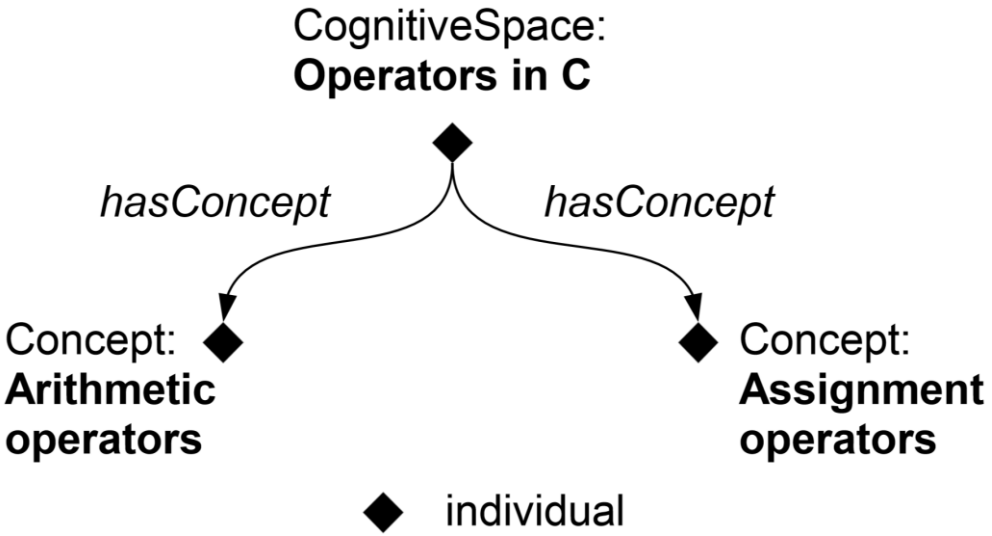
Cognitive and information spaces creating process scenarios

1) Individual creation of the information space

2) Collaborative creation of the information space

3) Creating the information space on the base of existing information space

The fragment of the cognitive space ontology for «Programming Language C» domain (the result of creating the cognitive space)



Creating the information space from scratch: define the relation associate between the concept and the information resource

information_space – instance of class InformationSpace, corresponding to the new information space
information_resource – annotating information resource (instance of class InformationResource)
concept – represented concept (instance of class Concept)

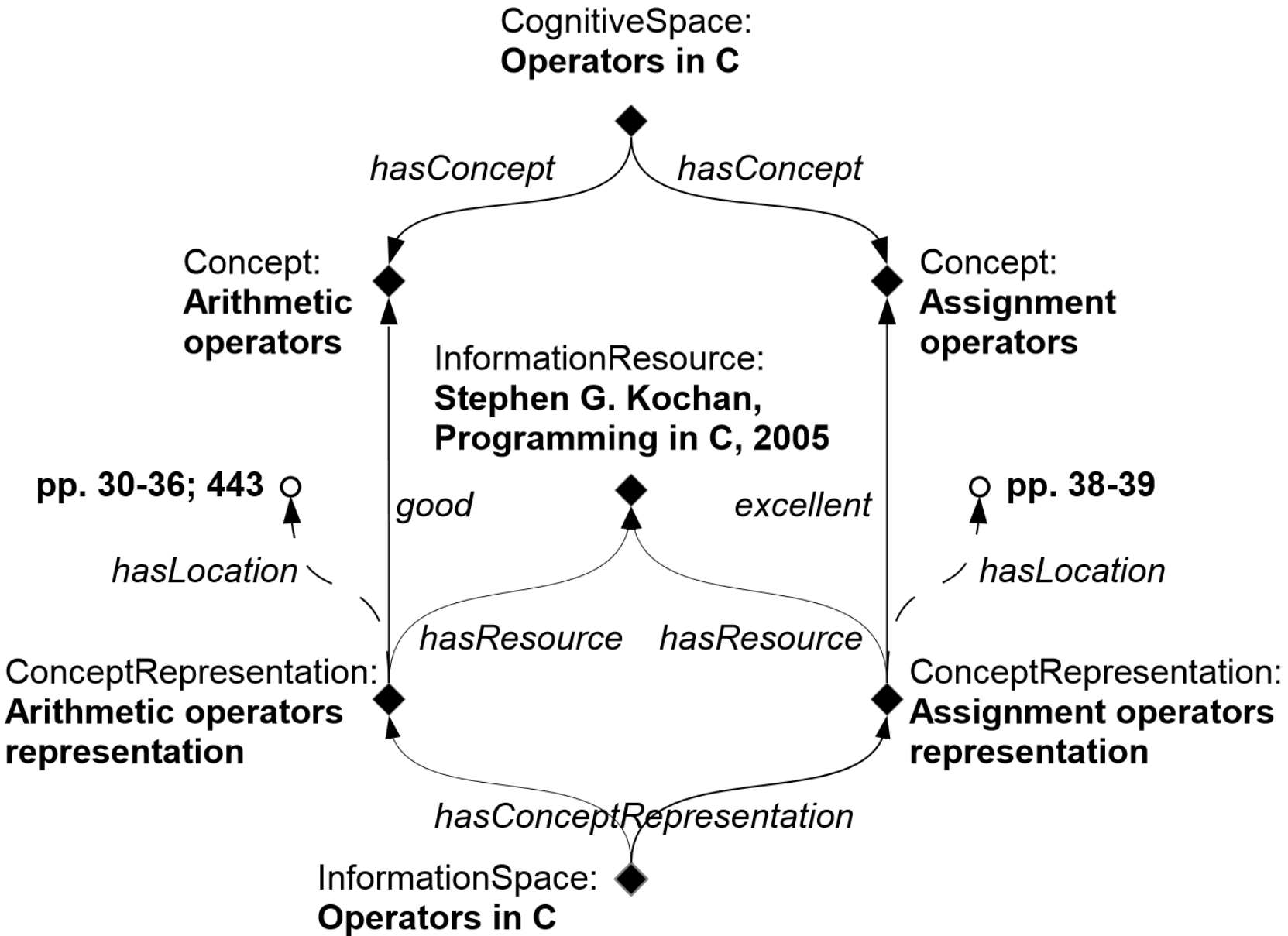
1) Define the instance concept_representation of the class ConceptRepresentation

2) Define the relation hasConceptRepresentation between the instances information_space and concept_representation

3) Define the relation hasConceptRepresentation between the instances concept_representation and information_resource

4) Define the relation from the set {undefined, bad, good, excellent} between the instances concept_representation and concept

The ontology of information space for «Programming Language C» domain

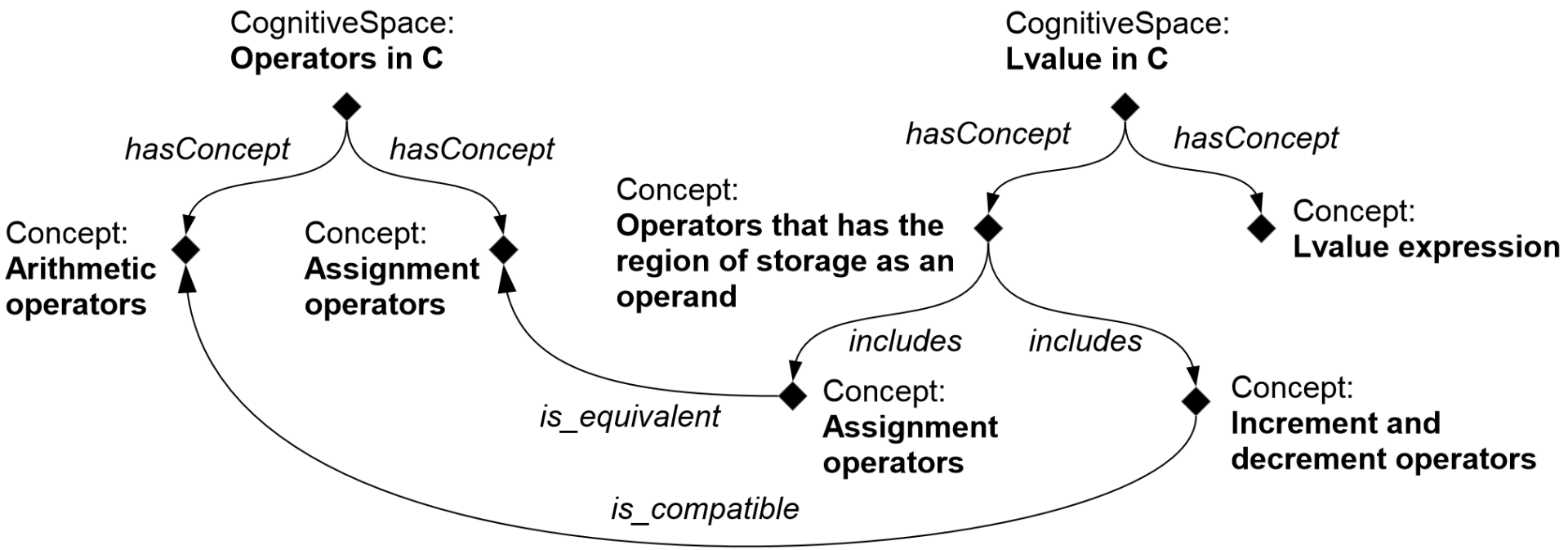


Creating the information space on the base of existing information space: top level

InformationSpace_1 – new information space,
InformationSpace_2 – the existing information space,
CognitiveSpace_1 – cognitive space for new information space,
CognitiveSpace_2 – cognitive space for existing information space,
concept – concept of cognitive space CognitiveSpace_1 (instance of class Concept),
concept_representation – associative relation between concept and information resource in the information space InformationSpace_1

1) Define the relations from the set of is_equivalent, is_compatible between instances of the class Concept that belong to the different cognitive spaces CognitiveSpace_1 and CognitiveSpace_2
2) Create the information space InformationSpace_1 on the basis of the existent information space InformationSpace_2 and the correspondences between the cognitive spaces CognitiveSpace_1 and CognitiveSpace_2
3) If necessary, redefine the relation from the set {undefined, bad, good, excellent} between the instances concept_representation and concept in the new information space InformationSpace_1

The example of association of two cognitive spaces



Creating the information space on the base of existing information space: define the relations between the concepts and information resources

InformationSpace_1 – new information space,
InformationSpace_2 - the existent information space,
CognitiveSpace_1 - cognitive space for new information space,
CognitiveSpace_2 - cognitive space for new information space

1) Define the instance information_space_1 of the class InformationSpace for the new information space

2) **For each** information resource from the InformationSpace_2 that is relevant for concepts of the cognitive space CognitiveSpace_2:

2.1) Define the instance concept_representation_1 of the class ConceptRepresentation

2.2) Set the relation hasResource between the instance concept_representation_1 and the instance of the class InformationResource, belonging to the InformationSpace_2

3) **For each** instance concept_representation_1 defined above:

3.1) Set the relation hasConceptRepresentation between the instances informaton_space_1 and concept_representation_1

3.2) Set the relation "associates" with one of the instances of the class Concept belonging to the CognitiveSpace_1

Creating the information space on the base of existing information space: SWRL-rules

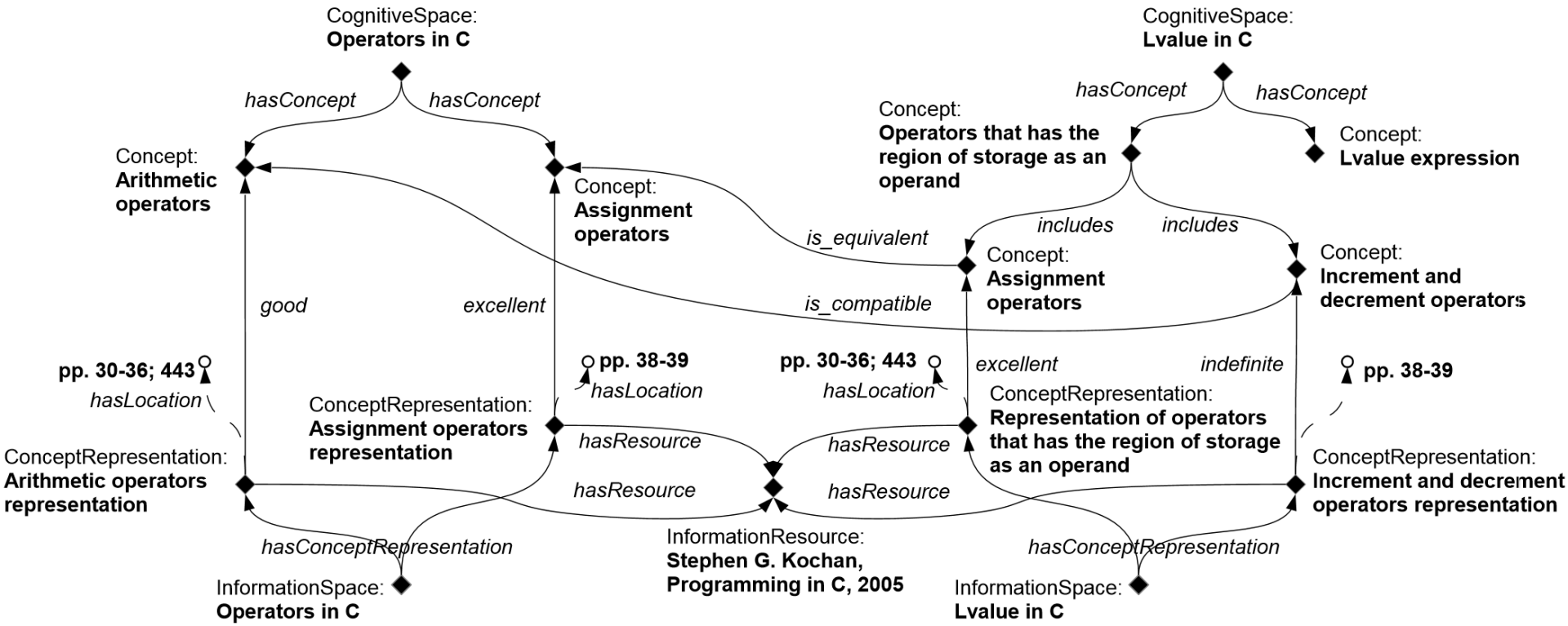
The SWRL-rules for the association of the two information spaces

hasConceptRepresentation (?is1, ?cr1) ^ hasConceptRepresentation (?is2, ?cr2) ^ hasResource(?cr1, ?res)^ good(?res, ?c1) ^ is_equivalent(?c2, ?c1) ^ sameAs(?cr1, ?c1) ^ sameAs(?cr2, ?c2) -> hasResource(?cr2, ?res) ^ good(?res, ?c2) (5)

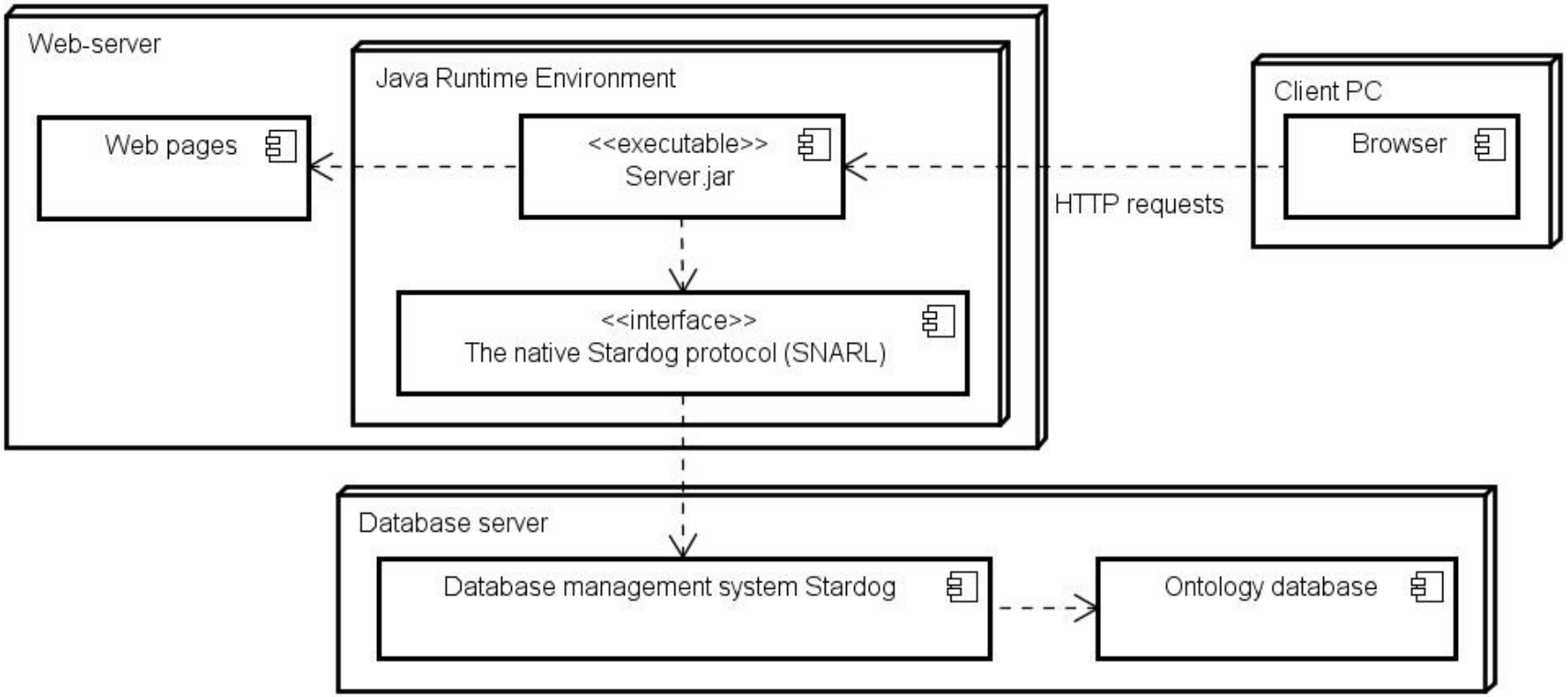
hasConceptRepresentation (?is1, ?cr1) ^ hasConceptRepresentation (?is2, ?cr2) ^ hasResource(?cr1, ?res)^ good(?res, ?c1) ^ is_compatible(?c2, ?c1) ^ sameAs(?cr1, ?c1) ^ sameAs(?cr2, ?c2) -> hasResource(?cr2, ?res) ^ indefinite(?res, ?c2) (6)

where *?is1, ?is2, ?c1, ?c2, ?cr1, ?cr2, ?res* - the variables of the SWRL rules.

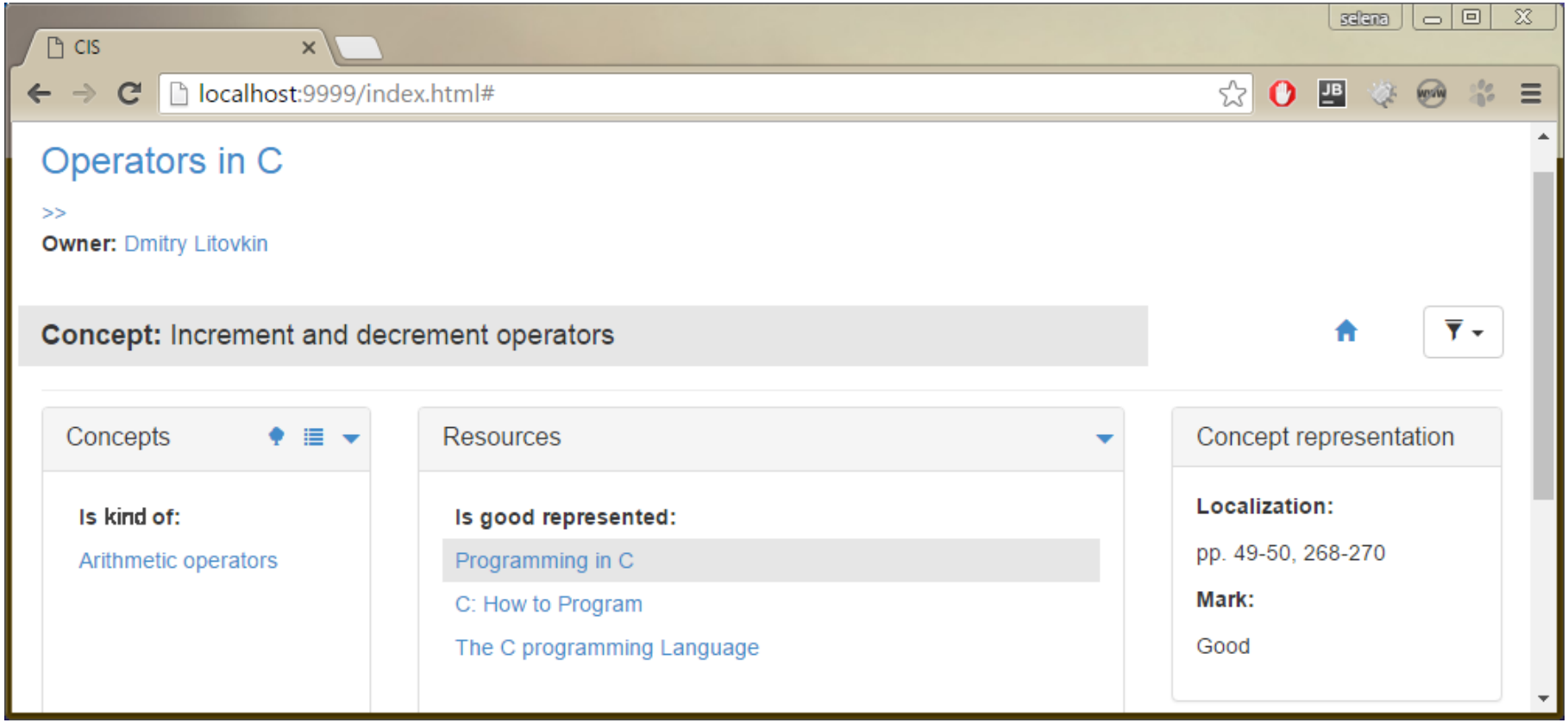
The example of association of two information spaces



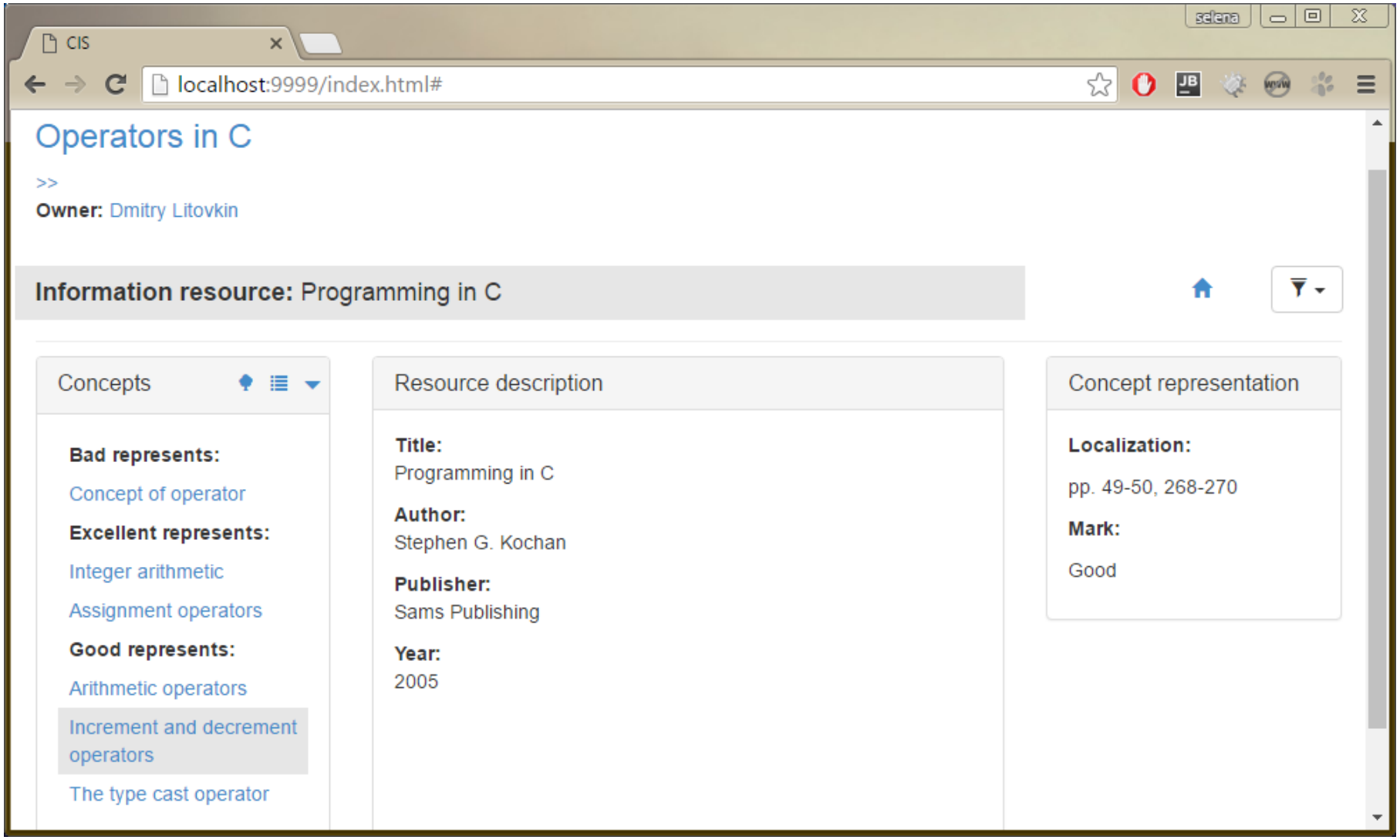
Cognitive-information space editor architecture



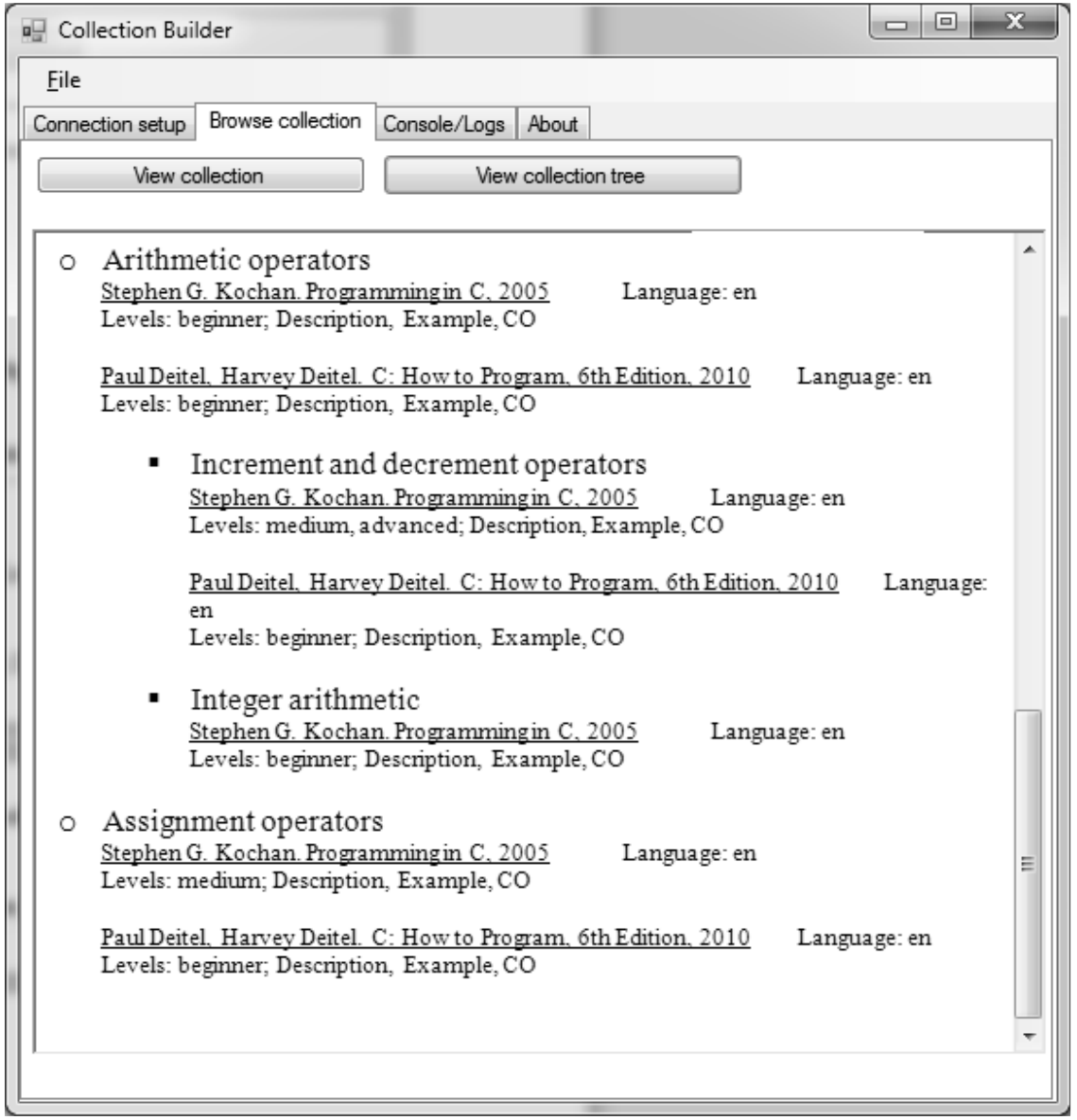
Cognitive-information space editor: concepts



Cognitive-information space editor: resources



Personal Collection Builder



Personal Collection: Quality Assessment Results

Testing conditions:

1) the number of learning resources in the repository – 50
2) the number of tutors - 4
3) the number of students - 20
4) the number of created collections - 20

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 ontology-based approach to collaborative construction of the domain information space on the base of the cognitive spaces of individual or group and the existing information spaces was proposed
- ✓ This approach allows to decrease the time and increase the efficiency of retrieval and reuse of the information resources which are relevant to the subject domain and the cognitive space of the information process subject
- ✓ Developed models, method and software tools were successfully applied for creation of information space in the form of personal learning collection for the course "Programming Languages. C++" in Volgograd State Technical University

This paper presents the results of research carried out under the RFBR grant 15-07-03541 Intelligent support of decision making in management of large scale systems on the base of integration of different types of reasoning on ontological knowledge

Further Work

- ✓ Implementation of the cognitive and information spaces retrieval from the repository
- ✓ Implementation of the concept retrieval from the information space
- ✓ Implementation of the information space navigation for define more exactly the search query and the information needs


¿Questions?