


Centre
de Recherche
en Automatique
de Nancy
UMR 7039



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Laboratoire lorrain de recherche
en informatique et ses applications


SEMANTIC ANNOTATIONS FOR SYSTEMS INTEROPERABILITY IN A PLM ENVIRONMENT

(ANNOTATIONS SÉMANTIQUES POUR L'INTEROPÉRABILITÉ DES SYSTÈMES
DANS UN ENVIRONNEMENT PLM)


Thesis Defence
14/11/2013

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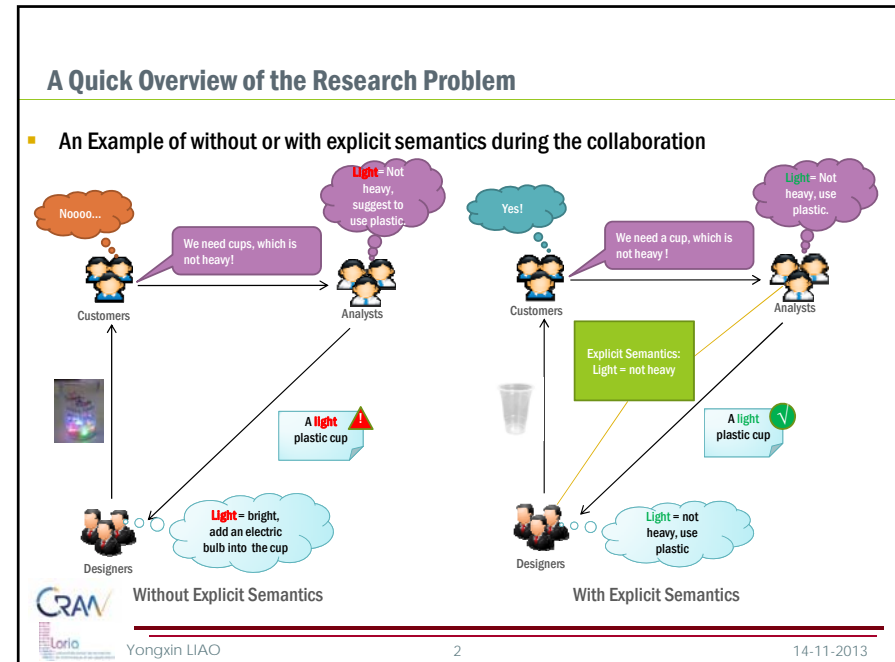
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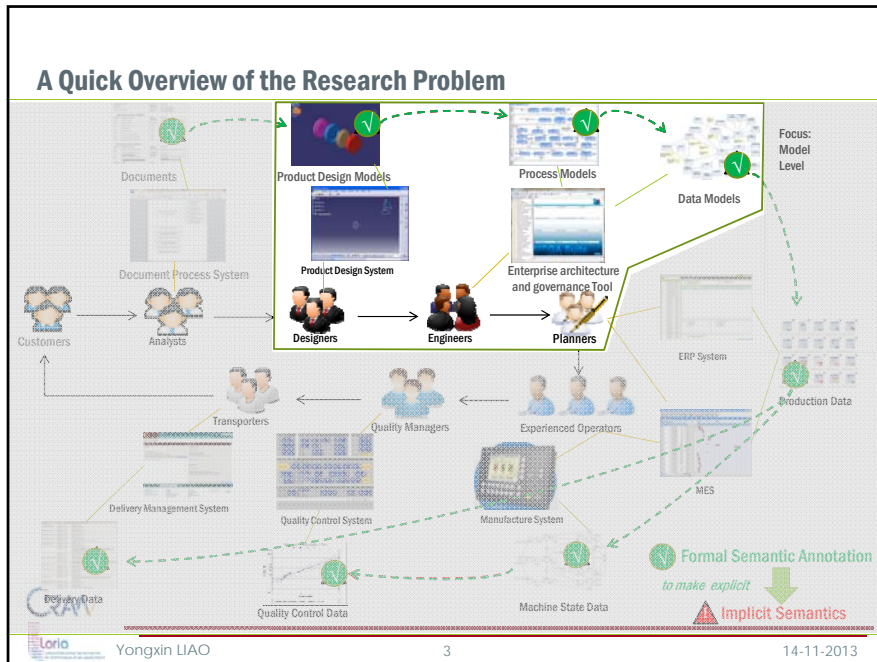


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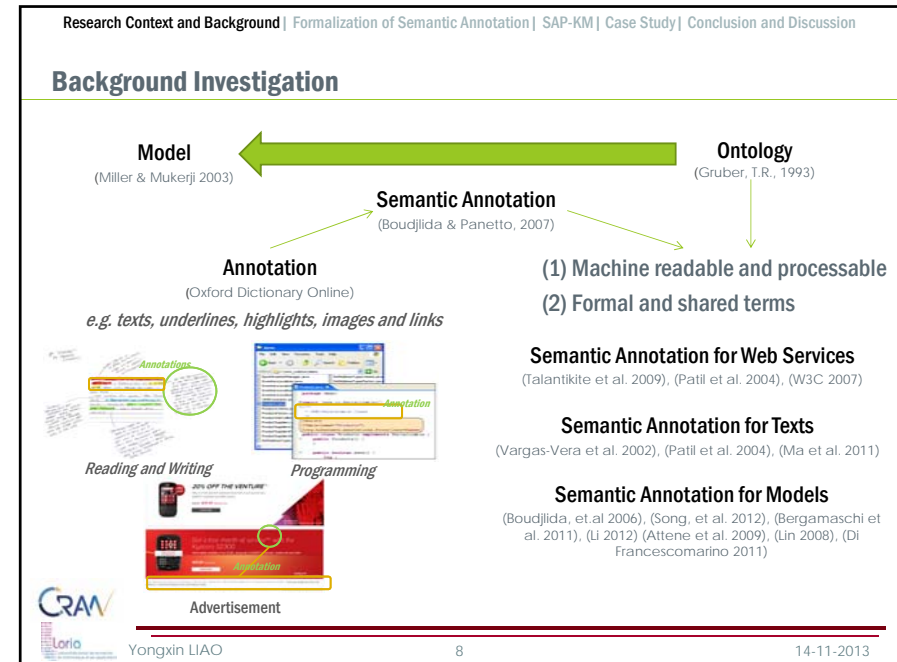
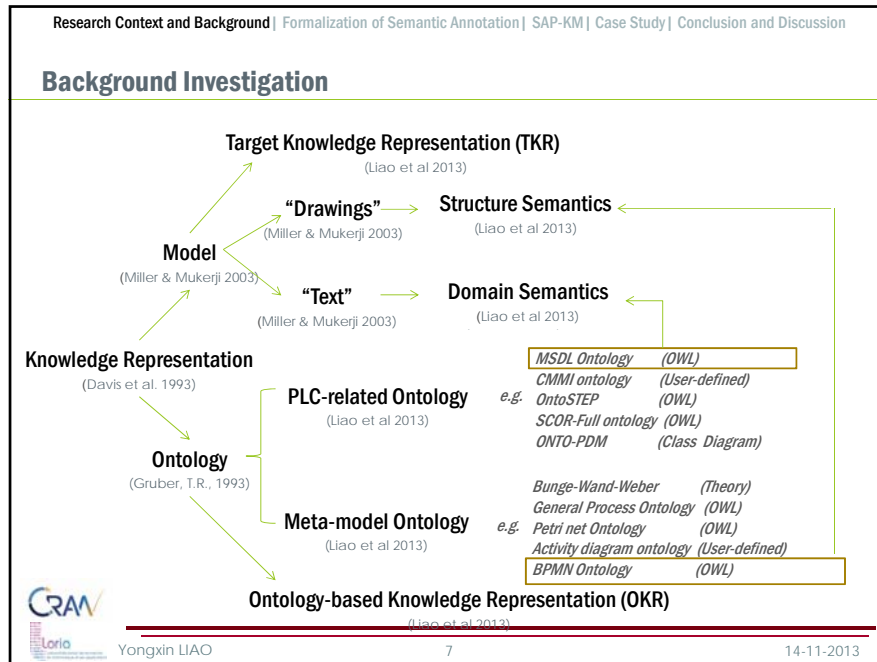


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- ### Outline
- 1. Research Context and Background**
 - Research Context
 - Research Problems
 - Background Investigation
 - Postulates and Research Focus
 - 2. Formalization of Semantic Annotation**
 - Overview of the Method
 - Meta-model of a semantic annotation
 - Semantic Blocks
 - Formal Definitions
 - Reasoning Mechanisms
 - Semantic Annotation Framework
 - 3. SAP-KM**
 - Overview of SAP-KM
 - Design and Implementation of SAP-KM
 - 4. Case Study**
 - Overview of Application Scenario
 - Preparation
 - Annotation
 - Reasoning
 - 5. Conclusion and Discussion**
 - Contributions
 - Limitations and Perspectives
- Yongxin LIAO 4 14-11-2013



Background Investigation

- Existing Drawbacks

- 1) Lack of a formalization of semantic annotations that is able to be used for the semantic enrichments of different kinds of models;
- 2) Lack of a mechanism to combine both structure and domain semantics together to contribute in the inference process.
- 3) Lack of a mechanism to assist the detection of inconsistencies between semantic annotations and the identification of conflicts between annotated objects.

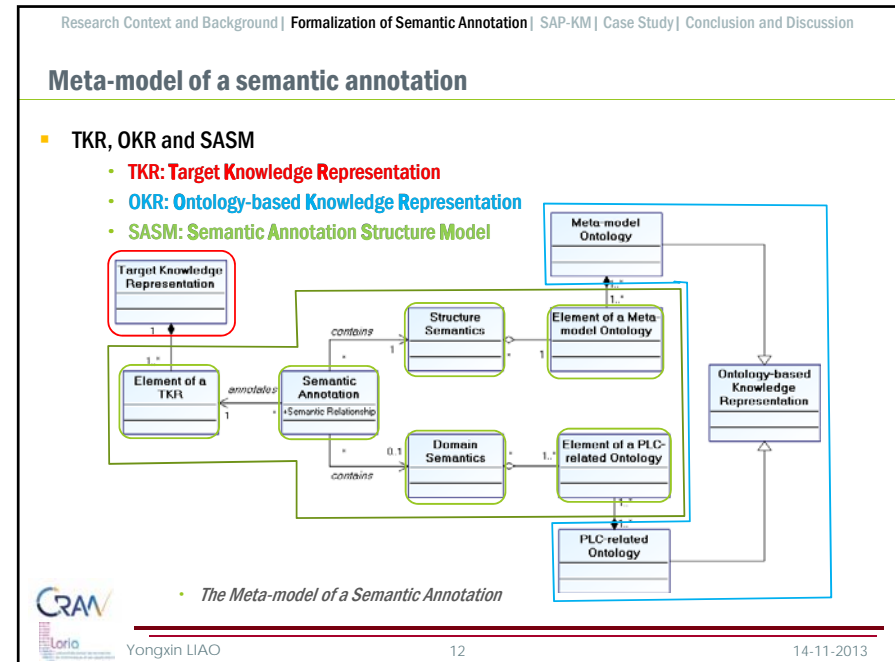
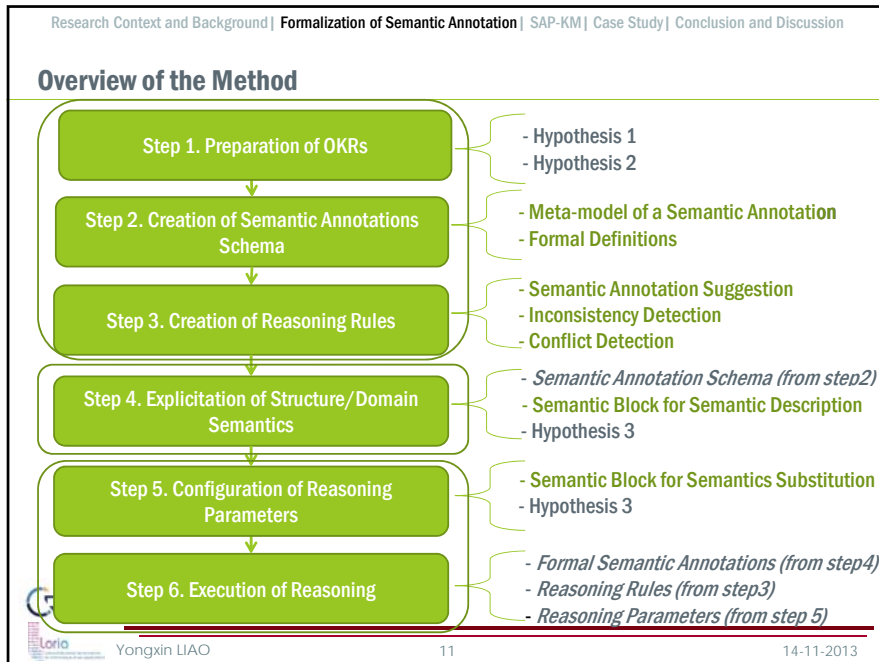
Postulates and Research Focus

- Postulates

- H1 All the knowledge that is needed for the semantic enrichment of models has already been captured, represented and formalized.
- H2 The corresponding interconnections among all the used ontologies have already been prepared.
- H3 The semantic similarity between two objects can be compared.

- Research Focus

Formalization of Semantic Annotations for Assisting Semantic Interoperability in the model level



Research Context and Background | Formalization of Semantic Annotation | SAP-KM | Case Study | Conclusion and Discussion

Formal Definitions

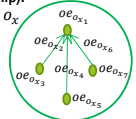
E is a set of elements from a "TKR" ← "Structure Semantic" of a "TKR"

$SA := (E, P, SR, MME, MR)$

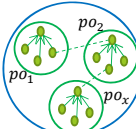
← "Domain Semantic" of a "TKR"

What is P ?

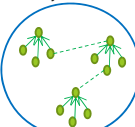
(1) - Let o_x be an ontology
 - Let $oall_{o_x}$ be composed of a set of ontology element $oe_{o_{xy}}$ (Concept or Relationship).
 $o_x := (C_{o_x}, R_{o_x}, A_{o_x})$
 $oall_{o_x} = \{oe_{o_{xy}} | oe_{o_{xy}} \in C_{o_x} \cup R_{o_x}\}$



(2) - Let PO be a set of PLC-related ontologies
 $PO = \{po_1, po_2, \dots, po_x\}$

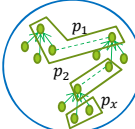



(3) Let $\bigcup_{o_x \in PO} oall_{o_x}$ be the arbitrary union of elements in PO
 $\bigcup_{o_x \in PO} oall_{o_x} = \{oe_{o_{xy}} | (\exists o_x)(o_x \in PO \wedge oe_{o_{xy}} \in oall_{o_x})\}$



(4) Then P is one subset of $\bigcup_{o_x \in PO} oall_{o_x}$

$P = \{p_1, p_2, \dots, p_x\}$
 $P \subseteq \mathcal{P}(\bigcup_{o_x \in PO} oall_{o_x})$





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13

14-11-2013

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Formal Definitions

E is a set of elements from a "TKR" ← "Structure Semantic" of a "TKR"

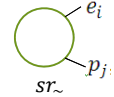
$SA := (E, P, SR, MME, MR)$

← "Domain Semantic" of a "TKR"

What is SR ?

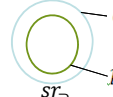
- SR is a set of binary relations that describe the semantic relationships from E to P .
 Given $e_i \in E$ and $p_j \in P$

$sr_{\sim} := \{(e_i, p_j) | sem(e_i) \text{ and } sem(p_j) \text{ are equivalent}\};$
 $sr_{\supseteq} := \{(e_i, p_j) | sem(e_i) \text{ is more general than } sem(p_j)\};$
 $sr_{\subseteq} := \{(e_i, p_j) | sem(e_i) \text{ is less general than } sem(p_j)\};$
 $sr_{\cap} := \{(e_i, p_j) | e_i \text{ and } p_j \text{ have common semantics, } (e_i, p_j) \notin sr_{\sim} \cup sr_{\supseteq} \cup sr_{\subseteq}\};$
 $sr_{\perp} := \{(e_i, p_j) | e_i \text{ and } p_j \text{ have not common semantics}\}$




sr_{\sim}

is equivalent to



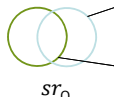
sr_{\supseteq}

subsumes



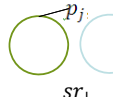
sr_{\subseteq}

is subsumed by




sr_{\cap}

intersects



sr_{\perp}

is disjoint with

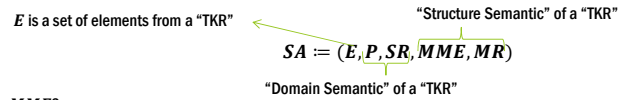


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14

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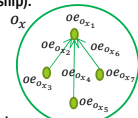
Formal Definitions



What is MME?

- (1) - Let o_x be an ontology
- Let $oall_{o_x}$ be composed of a set of ontology element $oe_{o_{xy}}$ (Concept or Relationship).

$o_x := (C_{o_x}, R_{o_x}, A_{o_x})$
 $oall_{o_x} = \{oe_{o_{xy}} | oe_{o_{xy}} \in C_{o_x} \cup R_{o_x}\}$



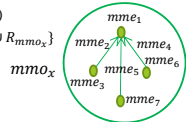
What is MR?

-MR is a set of binary relations that describe the semantic relationship from E to MME . Given $e_i \in E$ and $mme_l \in MME$

$mr_{i0} := \{(e_i, mme_l) | e_i \text{ is an instance of } mme_l\}$

- (2) - Let mmo_x be a meta-model ontology
- Then MME is composed of a set of ontology element mme_l (Concept or Relationship).

$mmo_x := (C_{mmo_x}, R_{mmo_x}, A_{mmo_x})$
 $MME := \{mme_l | mme_l \in C_{mmo_x} \cup R_{mmo_x}\}$



Semantic Blocks

$SB_{a_{i_0}} := (A_{a_{i_0}}, B_{a_{i_0}})$

Semantic Blocks for Semantic Description
 (Liao et al. 2013)

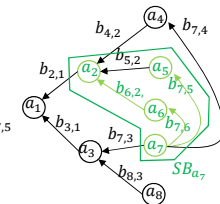
Semantic Block
 (Yahia et al. 2012)

Semantic Blocks for Semantic Substitution
 (Liao et al. 2013)

An example

Let a_7 be the selected main entity of SB_{a_7} .
 Let $B_{a_7} = \{b_{7,6}, b_{7,5}, b_{6,2}\}$ be the selected relations.
 The procedure to get A_{a_7} is as follows:

- (1) $A_{a_7,0} = \{a_7\}$
 - (2): $b_{7,6}, b_{7,5} \in B_{a_7}; (a_7, a_6) = b_{7,6}; (a_7, a_5) = b_{7,5}$
 $\therefore A_{a_7,1} = \{a_6, a_5\}$
 - (3): $b_{6,2} \in B_{a_7}; (a_6, a_2) = b_{6,2};$
 $\therefore A_{a_7,2} = \{a_2\}$
- $A_{a_7} = A_{a_7,0} \cup A_{a_7,1} \cup A_{a_7,2} = \{a_2, a_5, a_6, a_7\};$
 $SB_{a_7} = (A_{a_7}, B_{a_7})$



Research Context and Background | Formalization of Semantic Annotation | SAP-KM | Case Study | Conclusion and Discussion

Reasoning Mechanisms- Semantic Annotation Suggestion

Semantic Annotation
 (Boudjlida & Panetto, 2007)

Initial Semantic Annotation (Liao et al 2013) $\xrightarrow{\text{Suggestion}}$ Inferred Semantic Annotation (Liao et al 2013)

An Example

Domain Semantics of "Turning" and "Lathe" from Wordnet

Turning: the activity of shaping something on a lathe

Lathe: the machine tool for shaping metal or wood

"metal or wood" has input

Domain Semantics of "Turning" and "Lathe"

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Semantic Blocks

For example

$SB_{a_{i_0}} := (A_{a_{i_0}}, B_{a_{i_0}}),$

Semantic Blocks for Semantic Description
 (Liao et al. 2013)

Semantic Block
 (Yahia et al. 2012)

Semantic Blocks for Semantic Substitution
 (Liao et al. 2013)

$SBR_{a_i, a_j} := (A_{a_i, a_j}, B_{a_i, a_j})$

Model

Meta-Model (OMG 2011)

(1) **Relation Explication Rule**

- $A = \{a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9, a_{10}, a_{11}, a_{12}\}$
- $B = \{b_{1,6}, b_{6,5}, b_{4,5}, b_{5,7}, b_{8,7}, b_{2,8}, b_{7,9}, b_{3,11}, b_{11,10}, b_{9,10}, b_{10,12}\}$

where

- a_1, a_2, a_3 are instances of **DataObject**
- a_4, a_7, a_{10} are instances of **SequenceFlow**
- a_5, a_9, a_{12} are instances of **Task**
- a_6, a_8, a_{11} are instances of **Association**
- $b_{1,6}, b_{2,8}, b_{3,11}, b_{5,7}, b_{9,10}$ are **SourceRef**
- $b_{6,5}, b_{8,7}, b_{11,10}, b_{4,5}, b_{7,9}, b_{10,12}$ are **TargetRef**

(2) **Delimitation Rule (SBR_{a_i, a_j})**

Select "**DataObject**" and "**Task**"

$A_{DataObject, Task} = \{ "Association", "SequenceFlow" \}$

$B_{DataObject, Task} = \{ "SourceRef", "TargetRef", "TargetRef" \}$

$SBR_{DataObject, Task} = (A_{DataObject, Task}, B_{DataObject, Task})$

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Reasoning Mechanisms- Inconsistency Detection

Let the e_i be annotated by p_x and p_y

i. Given the semantic relationship between p_x and p_y
 $pr_{\sim}, pr_{\supset}, pr_{\subset}, pr_{\cap}, pr_{\perp}$

ii. Detection results

- sa_x and sa_y are consistent with each other
- sa_x and sa_y are possible consistent with each other
- there is an inconsistency between sa_x and sa_y .

An example of Inconsistency Detection

Inconsistency Detection Table

	e_i ST_C p_x	e_i ST_C p_y	e_i ST_C p_x	e_i ST_C p_y	e_i ST_C p_x	e_i ST_C p_y
e_i ST_C p_x	(a) p_x pr_{\subset} p_y (c) Others	(a) p_x pr_{\subset} p_y (c) Others	(a) p_x pr_{\subset} p_y (c) Others	(a) p_x pr_{\subset} p_y (c) Others	(a) p_x pr_{\subset} p_y (c) Others	(a) p_x pr_{\subset} p_y (c) Others
e_i ST_C p_y	(a) p_x pr_{\supset} p_y (c) Others	(b) p_x pr_{\supset} p_y p_x pr_{\supset} p_y p_x pr_{\cap} p_y p_x pr_{\perp} p_y	(a) p_x pr_{\supset} p_y (c) Others	(b) p_x pr_{\supset} p_y p_x pr_{\cap} p_y (d) Others	(a) p_x pr_{\supset} p_y (c) Others	(b) p_x pr_{\supset} p_y p_x pr_{\cap} p_y (c) Others
e_i ST_C p_x	(a) p_x pr_{\subset} p_y (c) Others	(a) p_x pr_{\subset} p_y (c) Others	(b) p_x pr_{\subset} p_y p_x pr_{\subset} p_y p_x pr_{\cap} p_y (c) Others	(b) p_x pr_{\subset} p_y p_x pr_{\cap} p_y (c) Others	(a) p_x pr_{\subset} p_y (c) Others	(b) p_x pr_{\subset} p_y p_x pr_{\cap} p_y (c) Others
e_i ST_C p_y	(a) p_x pr_{\supset} p_y (c) Others	(a) p_x pr_{\supset} p_y (c) Others	(b) p_x pr_{\supset} p_y p_x pr_{\supset} p_y p_x pr_{\cap} p_y (c) Others	(b) p_x pr_{\supset} p_y p_x pr_{\cap} p_y (c) Others	(a) p_x pr_{\supset} p_y (c) Others	(b) p_x pr_{\supset} p_y p_x pr_{\cap} p_y (c) Others
e_i ST_C p_x	(a) p_x pr_{\subset} p_y (c) Others	(a) p_x pr_{\subset} p_y (c) Others	(b) p_x pr_{\subset} p_y p_x pr_{\subset} p_y p_x pr_{\cap} p_y (c) Others	(b) p_x pr_{\subset} p_y p_x pr_{\cap} p_y (c) Others	(a) p_x pr_{\subset} p_y (c) Others	(b) p_x pr_{\subset} p_y p_x pr_{\cap} p_y (c) Others
e_i ST_C p_y	(a) p_x pr_{\supset} p_y (c) Others	(a) p_x pr_{\supset} p_y (c) Others	(b) p_x pr_{\supset} p_y p_x pr_{\supset} p_y p_x pr_{\cap} p_y (c) Others	(b) p_x pr_{\supset} p_y p_x pr_{\cap} p_y (c) Others	(a) p_x pr_{\supset} p_y (c) Others	(b) p_x pr_{\supset} p_y p_x pr_{\cap} p_y (c) Others

(b) p_x pr_{\sim} p_y

p_x pr_{\subset} p_y

p_x pr_{\supset} p_y

p_x pr_{\cap} p_y

(c) Others

CRAW $p_{18} pr_{\subset} p_1$ $p_{17} pr_{\perp} p_1$ $p_{18} pr_{\cap} p_{17}$

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Research Context and Background | Formalization of Semantic Annotation | SAP-KM | Case Study | Conclusion and Discussion

Reasoning Mechanisms-Conflict Identification

Let the e_i be annotated by p_x and p_y

i. Given the semantic relationship between p_x and p_y
 $pr_{\sim}, pr_{\supset}, pr_{\subset}, pr_{\cap}, pr_{\perp}$

ii. Detection results

- sa_x and sa_y are consistent with each other
- sa_x and sa_y are possible consistent with each other
- there is an inconsistency between sa_x and sa_y .

An example of Inconsistency Detection

Conflict Identification Table

The sa_x on e_i is an	Initial Semantic Annotation	Inferred Semantic Annotation (inferred from the semantic annotation of e_j)
The sa_y on e_j is an	Initial Semantic Annotation	Between e_i and e_j , one of them is possibly wrong
Inferred Semantic Annotation (inferred from the semantic annotation of e_i)	Between e_i and e_j , one of them is possibly wrong	Between e_j and e_i (if $e_j \neq e_i$), one of them is possibly wrong

Because (1) p_{17} and p_1 is in consistent with each other
 (2) p_1 is initial semantic annotation (of e_3)
 (3) p_{17} is inferred semantic annotation (from e_1)
 => Between e_3 and e_1 , one of them is possibly wrong

CRAW $p_{18} pr_{\subset} p_1$ $p_{17} pr_{\perp} p_1$ $p_{18} pr_{\cap} p_{17}$

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Research Context and Background | Formalization of Semantic Annotation | SAP-KM | Case Study | Conclusion and Discussion

Semantic Annotation Framework

- Semantic Annotation Procedure
 - The Preparation Phase
 - TKR (by **modeller**)
 - OKRs (by **knowledge engineer**)
 - Semantic Annotation Schema (by **Plug-in developer**)
 - The Annotation Phase
 - Explication of Structure Semantics (by **annotator**)
 - Explication of Domain Semantics (by **annotator**)
 - The Reasoning Phase
 - Configuration of Reasoning Parameters (by **annotator**)
 - Reasoning (by **annotator**)

Start

The Preparation Phase

Collection and Formalization of OKRs

Creation of a TKR

Customization of the SA Solution

The Annotation Phase

Explication of Structure Semantics

Explication of Domain Semantics

The Reasoning Phase

Configuration of Reasoning Parameters

Reasoning on Semantic Annotations

Results

End

Legend

- Process
- Start/End
- Flow
- Parallel
- Line between Phases

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Research Context and Background | Formalization of Semantic Annotation | SAP-KM | Case Study | Conclusion and Discussion

Semantic Annotation Framework

- Semantic Annotation Framework
 - TKR Creation and Management module
 - OKR Creation and Management module
 - Knowledge Cloud module
 - Reasoning Engine module
 - Semantic Annotation and Processing Agent

Analysis of Requirement

Product Engineering

Manufacturing Engineering

Production Planning

Manufacturing

Sales and Distribution

After Sales Service

Recycling

TKR Creation and Management

Product Information

Standards

Requirements

OKR Creation and Management

Knowledge Cloud

Reasoning Engine

SAPA

Request and Feedback

Process Flow

Collection

Formalization

Interrelations

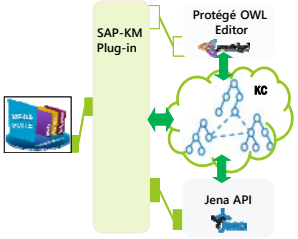
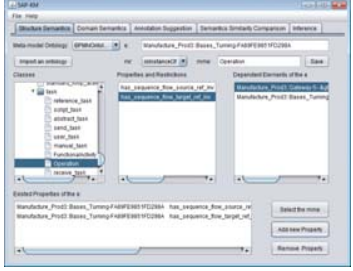
SAPA: Semantic Annotation and Processing Agent

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Research Context and Background | Formalization of Semantic Annotation | **SAP-KM** | Case Study | Conclusion and Discussion

Overview of SAP-KM (Semantic Annotation Plug-in for Knowledge Management)

- Development Environment Overview
 - TKR Creation and Management* module -> Mega Modelling Environment
 - OKR Creation and Management* module -> Protégé OWL Editor
 - Knowledge Cloud* module -> Microsoft Windows Folder System
 - Reasoning Engine* module -> Jena OWL reasoning engine
 - Semantic Annotation and Processing Agent* module -> SAP-KM Plug-in

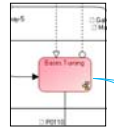

SAP-KM Overview

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Research Context and Background | Formalization of Semantic Annotation | **SAP-KM** | Case Study | Conclusion and Discussion

Design and Implementation of SAP-KM

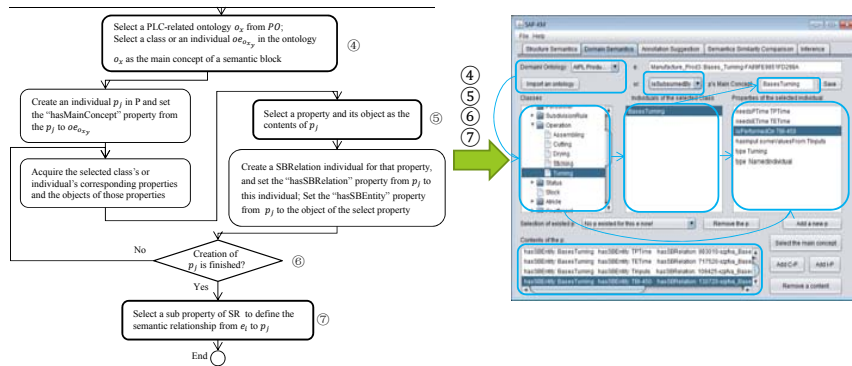
- The Design and Implementation of Annotation Phase
 - Explication of Structure Semantics
 - Flowchart:
 - Select an element X in a TKR Request for adding a SA
 - Acquire the ids and the names of X and its dependent elements
 - Decision: Do they exist in E?
 - Yes: Acquire the property restrictions on mme_i
 - No: Create them as individuals in the class E, in which e_i represents the model element X
 - Define the properties between e_i and its dependent elements
 - Set the properties between e_i and the selected elements as the selected properties
 - Mark the class Y as a sub class of the class MME, and mark e_i as an individual of the class mme_i
 - Select a PLC-related ontology o_2 from PO. Select a class or an individual oe_{e_2} in the ontology o_2 as the main concept of a semantic block

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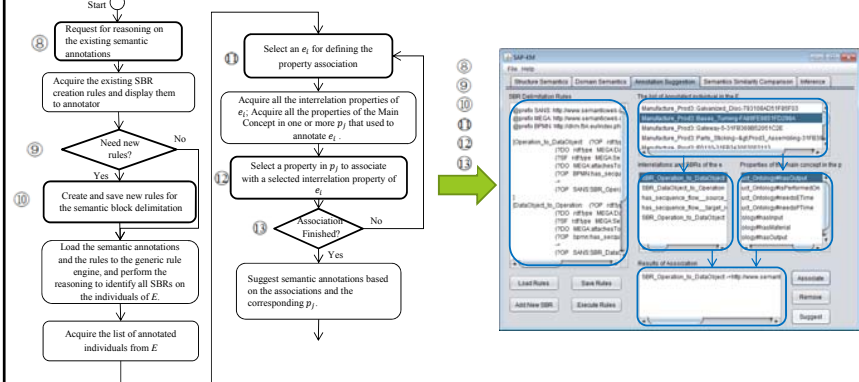
Design and Implementation of SAP-KM

- The Design and Implementation of Annotation Phase
 - Explication of Domain Semantics



Design and Implementation of SAP-KM

- The Design and Implementation of Reasoning Phase
 - Properties Association in Annotation suggestion



Research Context and Background | Formalization of Semantic Annotation | **SAP-KM** | Case Study | Conclusion and Discussion

Design and Implementation of SAP-KM

- The Design and Implementation of Reasoning Phase
 - Similarity Definition between two Domain Semantics

↓

Suggest semantic annotations based on the associations and the corresponding p_i .

↓

Acquire all the individuals of the class E, which have two or more semantic annotations.

↓

Define the semantic similarities between two domain semantics of the selected individual ¹³

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27

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Research Context and Background | Formalization of Semantic Annotation | **SAP-KM** | Case Study | Conclusion and Discussion

Design and Implementation of SAP-KM

- The Design and Implementation of Reasoning Phase
 - Reasoning Results

↓

Suggest semantic annotations based on the associations and the corresponding p_i .

↓

Acquire all the individuals of the class E, which have two or more semantic annotations.

↓

Define the semantic similarities between two domain semantics of the selected individual ¹³

↓

Make inference request ¹⁵

↓

Detect possible annotation inconsistencies based on similarity comparison results and inconsistency detection rules

↓

Identify possible model mistakes based on the mistake identification rules, the inconsistency detection results

↓

Display all the Results to the annotator

End

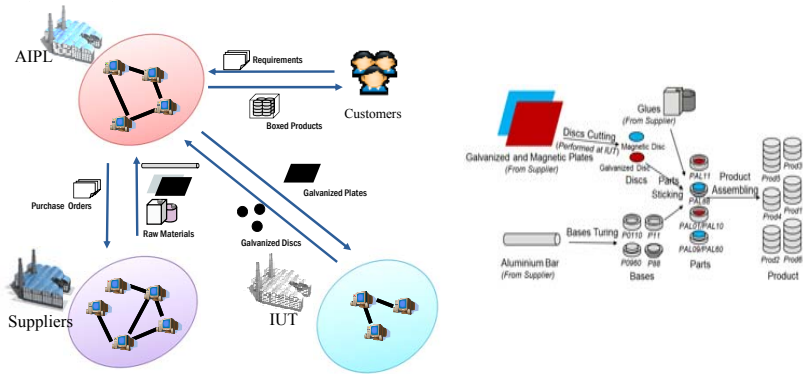
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28

14-11-2013

Application Scenario

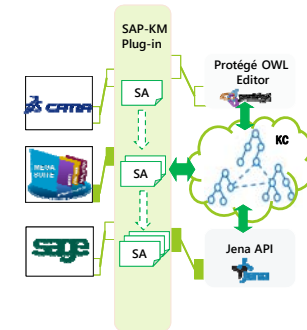
- **AIPL (Atelier Inter-Etablissements de Lorraine)**
It is a small scale facility for manufacturing products



Application Scenario

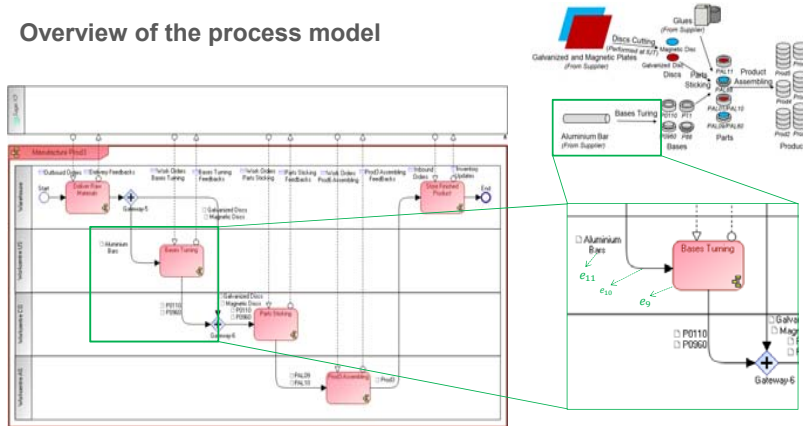
- **Outline of the Case Study**

- **Preparation Phase**
 - Overview of the process model
- **Annotation Phase**
 - Semantic Annotations from Upstream-System
 - Semantic Annotations in Current-System
 - Semantic Annotations for Downstream-System
- **Reasoning Phase**
 - Annotation Suggestion
 - Inconsistency detection and Conflict Identification



Preparation Phase

Overview of the process model

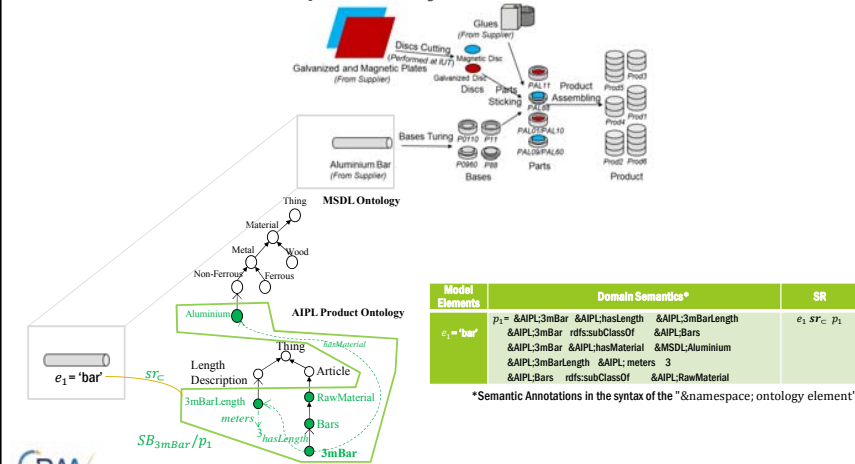


The Selected Model Elements in the Process Model



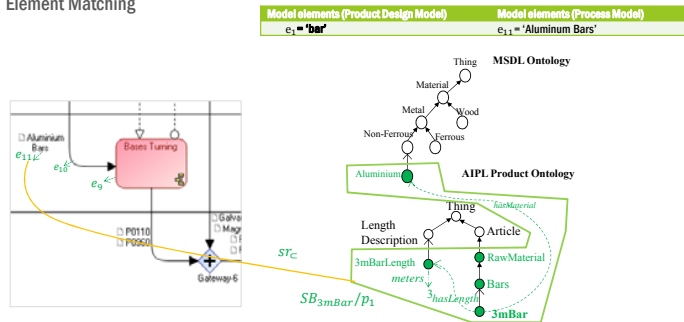
Annotation Phase

Annotation from the Upstream-System



Annotation Phase

- Annotation in the Current-system
 - The Explication of Domain Semantics
 - Element Matching

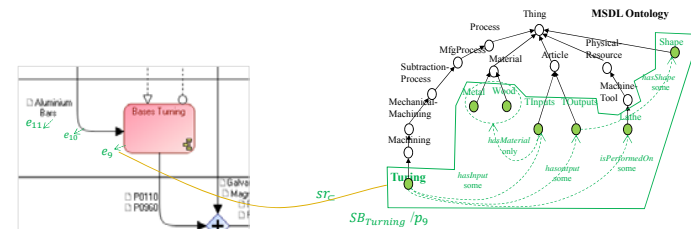


Model Elements	Domain Semantics	SR
e_{11} = 'Aluminium Bars'	p_1 = &AIPL3mBar &AIPL:hasLength &AIPL:3mBarLength &AIPL:3mBar rdfs:subClassOf &AIPL:Bars &AIPL:3mBar &AIPL:hasMaterial &MSDL:Aluminium &AIPL:3mBar.Length &AIPL: meters 3 &AIPL:Bars rdfs:subClassOf &AIPL:RawMaterial	e_{11} ST_C p_1



Annotation Phase

- Annotation in the Current-system
 - The Explication of Domain Semantics

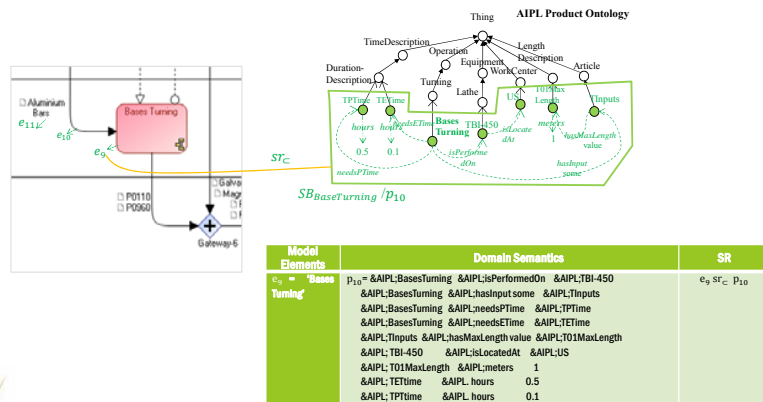


Model Elements	Domain Semantics	SR
e_{11} = 'Bases Turning'	p_9 = &MSDL:turning &MSDL:isPerformedOn some &MSDL:Lathe &MSDL:turning &MSDL:hasInput some &MSDL:Inputs &MSDL:turning &MSDL:hasOutput some &MSDL:Outputs &MSDL:Inputs &MSDL:hasMaterial only unionOf (&MSDL:Wood or &MSDL:Metal) &MSDL:Outputs &MSDL:hasShape some &MSDL:Shape	e_{11} ST_C p_9



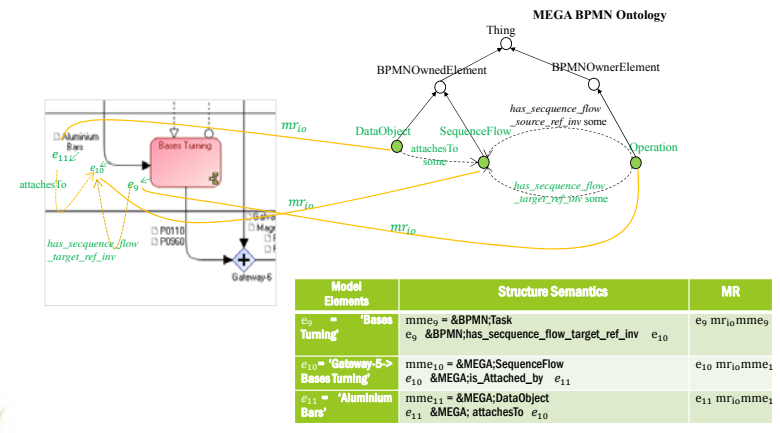
Annotation Phase

- Annotation in the Current-system
 - The Explication of Domain Semantics



Annotation Phase

- Annotation in the Current-system
 - The Explication of Structure Semantics



Research Context and Background | Formalization of Semantic Annotation | SAP-KM | Case Study | Conclusion and Discussion

Annotation Phase

- Annotation in for Downstream-system
 - Data Query

SPARQL Query

```

PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX SANS: <http://www.semanticweb.org/ontologies/2013/6/SemanticAnnotations#>
PREFIX AIPL: <http://www.semanticweb.org/ontologies/2013/6/AIPL_Product_Ontology#>
SELECT ?Process ?Machine ?WorkCenter ?TPTIME ?TETime
WHERE {
  ?P rdf:type SANS:P.
  ?P SANS:hasMainConcept ?Process.
  ?Process AIPL:isPerformedOn ?Machine.
  ?Machine AIPL:isLocatedAt ?WorkCenter.
  ?Process AIPL:needsETime ?TE.
  ?TE AIPL:hours ?TETime.
  ?Process AIPL:needsPTIME ?TP.
  ?TP AIPL:hours ?TPTIME.
}
    
```

Query Result

```

?P= AIPL: P1-Of-Manufacture_Prod3::Bases_Turning
-FAB9FE9851FD298A
?Process= AIPL:BasesTurning
?Machine= AIPL:TB1-450
?WorkCenter= AIPL:US
?TE= AIPL:TETime
?TETime=0.1
?TP= AIPL:TPTIME
?TPTIME=0.5
    
```

37

Research Context and Background | Formalization of Semantic Annotation | SAP-KM | Case Study | Conclusion and Discussion

Reasoning Phase

- Semantic Annotation Suggestion (1/2)
 - Semantic Block Delimitation (for semantics substitution)
 - Select concept "Operation" and "DataObject" to create `SBR_DataObject_to_Operation`
 - Select $A_{Operation, DataObject} = \{ \text{"SequenceFlow"} \}$
 $B_{Operation, DataObject} = \{ \text{"attachedTo"}, \text{"has_sequence_flow_target_ref_inv"} \}$
 - Delimitation rule

Delimitation rule

```

@prefix SANS: http://www.semanticweb.org/ontologies/2013/6/SemanticAnnotations#
@prefix MEGA: http://www.semanticweb.org/ontologies/2013/6/MEGA_BPMN#
@prefix BPMN: http://dkm.fbk.eu/index.php/BPMN_Ontology#

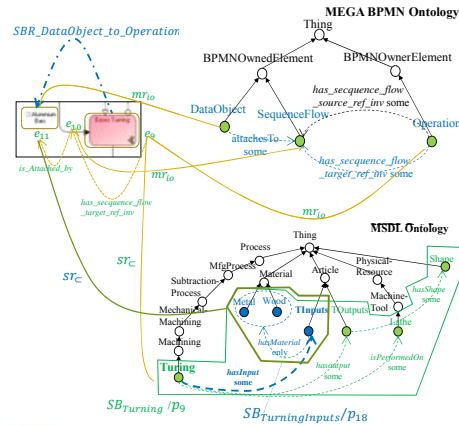
[DataObject_to_Operation: (?OP rdf:type MEGA:Operation)
(?DO rdf:type MEGA:DataObject)
(?SF rdf:type MEGA:SequenceFlow)
(?DO MEGA:attachedTo ?SF)
(?DO MEGA:has_sequence_flow_target_ref_inv ?SF)
]>
(?OP SANS:SBR_DataObject_to_Operation ?DO)
    
```

- ?OP = e_{10}, e_{12}, e_{21}
- ?DO = $e_{11}, e_{17}, e_{19}, e_{20}, e_{23}, e_{24}$ and e_{26}
- ?SF = e_{13}, e_{14} and e_{16}
- ?DO (e.g. e_{11}) "MEGA:attachedTo" ?SF (e.g. e_{13}).
- ?OP (e.g. e_{10}) "BPMN:has_sequence_flow_target_ref_inv" ?SR (e.g. e_{10})
- Adding "SANS:SBR_DataObject_to_Operation" property from ?OP (e.g. e_{10}) to ?DO (e.g. e_{11}).

38

Reasoning Phase

Semantic Annotation Suggestion (2/2)



- (2) Semantic Block Delimitation (for semantics description)
- a) Properties Association
 $SBR_DataObject_to_Operation$ and $hasInput$
 - b) $TInputs \in A_{turning}$ satisfies
 $(Tuning, TInputs) = hasInput$
 i) $A_{turningInputs,0} = \{TuningInputs\}$
 ii) Taking the $Tinputs$ as a starting point
 $\therefore B_{turning} = \{hasInput, hasOutput, isPerformedOn, hasMaterial, hasShape\}$
 $(TuningInputs, Wood) = hasMaterial;$
 $(TuningInputs, Metal) = hasMaterial$
 $\therefore A_{turningInputs,1} = \{Wood, Metal\}$
 $A_{turningInputs} = \{TuningInputs, Wood, Metal\};$
 $B_{turningInputs} = \{hasMaterial\}$
 $SB_{turningInputs} := (A_{turningInputs}, B_{turningInputs})$
 - c) $e_{11} ST_C P_{18} (SB_{turningInputs})$



Reasoning Phase

Inconsistency Detection and Conflict Identification

$p_{17} = \&AIPL:3mBar \&AIPL:hasLength \&AIPL:3mBarLength$
 $\&AIPL:3mBar rdfs:subClassOf \&AIPL:Bars$
 $\&AIPL:3mBar \&AIPL:hasMaterial \&MSDL:Aluminum$
 $\&AIPL:3mBarLength \&AIPL:meters 3$
 $\&AIPL:Bars rdfs:subClassOf \&AIPL:RawMaterial$

$p_{18} = \&MSDL:Tinputs \&MSDL:hasMaterial$ only
 unionOf ($\&MSDL:Wood$ or $\&MSDL:Metal$)
 $p_{18} \&SANS:isInferredFrom e_9$

$p_{17} = \&AIPL:Tinputs \&AIPL:hasMaxLength$ value $\&AIPL:T01MaxLength$
 $\&AIPL:T01MaxLength \&AIPL:meters 1$
 $p_{17} \&SANS:isInferredFrom e_9$

Inconsistency Decton

- (1) Get the semantic relationships between domain semantics of a common annotation object (manually performed)
 $p_{18} P_{17} \perp p_{17}, p_{17} P_{17} \perp p_{17}, p_{18} P_{17} \perp p_{17}$
- (2) Detect the results based on the Inconsistency detection table
 $p_{18} P_{17} \perp p_{17} \Rightarrow$ result type(b), possible consistent
 $p_{17} P_{17} \perp p_{17} \Rightarrow$ result type(c), inconsistent
 $p_{18} P_{17} \perp p_{17} \Rightarrow$ result type(b), possible consistent

Conflict Identification

- (1) Because (1) p_{17} and p_{18} is in consistent with each other
 - (2) p_{18} is initial semantic annotation (of e_{11})
 - (3) p_{17} is inferred semantic annotation (from e_9)
- \Rightarrow Between e_{11} and e_9 , one of them is possibly wrong



Conclusion

■ What are the essential elements of a semantic annotation and how can formal semantic annotations contribute to the semantic interoperability in a PLM environment?

(1) What are the semantic interoperability problems that exist during the cooperation in a PLM environment?

- The survey of product lifecycle, knowledge, system interoperability in this context of PLM

(2) What kinds of knowledge representation in a PLM environment need semantic enrichment?

- The survey of models in a PLM environment

(3) What kinds of ontology can be used to support the semantic enrichments of those knowledge representations?

- The survey of PLC-related ontologies and Meta-model ontologies

(4) What are the essential elements of a semantic annotation and how to formally represent a semantic annotation in a suitable format?

- The meta-model and the formal definitions of a semantic annotation

(5) How to semantically enrich a knowledge representation and how can these enriched semantics contribute to the semantic interoperability in a PLM environment?

- Two kinds of semantic blocks, Three reasoning mechanisms, A semantic annotation procedure and framework, A semantic annotation prototype



Discussion

■ Limitations

■ Limitations from the Hypothesis

- Cost of the creation of new ontologies
- Cost of the creation of interconnections
- Difficulties in semantic similarity measurement

• Limitations of the Case Study

- Lack of automatic assistances
- Incompleteness of SBR delimitation rules
- Small scale facility.

■ Perspectives

- To improve automatic assistances
- To complete SBR delimitation rules
- To apply this method in a larger scale facility
- To develop plug-in for other systems





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Thank You For Paying Attention!

Yongxin LIAO

