Evaluating PSI Ontologies by Mapping to the Common Sense

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Abstract: The paper presents the results of mapping of PSI Ontologies family to the foundational ontologies: WordNet, SUMO and DOLCE. The two main outcomes of the presented research are: reported manual technique may be used as initial evaluation of ontology claiming to be a golden standard for a new domain; and: usage of mentioned foundational ontologies for alignment of ontologies family of a given domain has shown differences between SUMO and DOLCE, two formal upper-level ontologies of common sense knowledge. The research reported was performed in the frame of our PSI project[1].

1 Introduction

Ontology as a shared and agreed specification of conceptualization [Gr93] still reflects the subjective views of its creators (knowledge engineers, domain experts etc). Indeed, it is possible to build different ontologies which formally represent the same body of knowledge. Ontology evaluation provides a way to select an ontology satisfying a set of predefined criteria, ranging from the presentation of the required level of structural knowledge granularity to matching the corpus of known factual information about the domain or task, acquired from appropriate documents or standards.

A "golden standard" ontology may exist for a domain if the formal specification of its conceptualization is shared and committed to by the majority of domain experts. This widely accepted ontology is normally used to develop knowledge-intensive applications or to formalize the corpus of domain facts and data. A newly developed ontology of such a domain may be evaluated against the "golden standard". Such an evaluation answers how well the evaluated ontology matches the existing applications and knowledge

[1] Performance Simulation Initiative (PSI) is the project of Cadence Design Systems, GmbH.

corpus – the agreement and the commitment of the majority of domain experts. A new ontology may also be evaluated against the set of non-formalized criteria, norms, rules characterizing the domain in question [BGM05].

However, "golden standard" theories do not exist for many interesting domains. If so, an ontology may be evaluated using a purely logical approach applying the techniques like OntoClean [GW01] or using statistical approaches [Ga05]. The weakness of these methodologies is that they provide meaningful results only for taxonomies. The question about how to reliably evaluate complex ontologies with richer relationships between their concepts is still open.

The paper proposes a partial answer to this important research question. In our approach a meta-layer of the evaluated ontology is built and the attempt to map it to the upper-level common sense ontologies is undertaken. If the ontology in question maps well to the common sense one may expect that the commitment of domain experts to it may be reached considerably easily. If the mapping is bad then the ontology is either the extension of the common sense conceptualization or is badly designed. The meta-layer is designed as a taxonomy. Therefore, formal logical or statistical frameworks mentioned above may be also used for its evaluation[2].

The answer proposed in the paper is to use human common sense, formalized in well defined and widely used foundational ontologies (such as CYC, DOLCE, SUMO), of a high level of abstraction, as a "golden standard". Ontology evaluation in this case is the process of mapping of the evaluated ontology to common sense – i.e. to one or more foundational ontologies. This process is obviously twofold: both a foundational ontology and the evaluated ontology may benefit from each other, as far as even the creation of foundational ontology is incremental. Evaluated domain ontology may benefit from detection of its discrepancies with common sense, which obviously may be the obstacle for ontological commitment. A foundational ontology may also benefit from the alignment of a new Domain ontology to it. Bad alignment results might be a signal to start thinking about the refinement of a foundational theory as well. Moreover, mapping to several foundational ontologies may also reveal the differences between the targets: different focuses, completeness, etc.

The focus of the paper is the evaluation of the PSI Ontologies Suite v.1.6 [Er06b] by mapping its ontologies to foundational ontologies taken as a „golden standard of a common sense". The approach is positioned as a kind of manual evaluation, where the criteria set is not a characteristic of the domain, but is the common sense knowledge. PSI Ontologies Suite is mapped to WordNet+SUMO and DOLCE. The two main results of the presented research are: (i) reported approach may be used for initial evaluation of an ontology aiming to become a prevailing theory of a domain which does not yet have a "golden standard"; and (ii) the usage of the mentioned foundational ontologies for alignment of ontologies family of a given domain has shown differences between SUMO and DOLCE, two formal upper-level ontologies of common sense knowledge.

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[2] Though it is not the focus of this paper.

The paper is structured as follows. Section 2 provides the overview of PSI Ontologies family and the role of PSI-Meta ontology. Section 3 surveys common sense and foundational ontologies and argues for the choice of WordNet+SUMO and DOLCE as the two theories being the "golden standard of a common sense". Section 4 describes the process and the results of the mapping of PSI Ontologies Suite to WordNet+SUMO and DOLCE, which are then concluded in Section 5. Section 6 analyses the related work in the field of ontology evaluation.

2 Overview of PSI Ontologies, PSI Meta

PSI project deals with the development of the methodology and the toolset for assessing and optimizing the Performance of Engineering Design Processes in microelectronics. Though the design technology in microelectronics Domain is well defined, many factors make Engineering Design Processes highly stochastic, non-deterministic, structurally ramified, time-bound – in a phrase, loosely defined and highly dynamic. The examples of such factors are: the human factor, the innovative character, the pace of technology change, the peculiarities of the market and customer requirements, etc. In difference to many alternative and competitive approaches to assessing the performance of engineering design, PSI goes deeper in the details of a process and uses simulation to observe a Dynamic Engineering Design Process (DEDP) in its real dynamics and with sufficiently detailed picture to make the assessment grounded. Besides, simulation allows playing "what-if" games to model the unpredictable character of the real business world of microelectronic design.

Due to the omnipresence of the mentioned factors which complicate and de-linearize the development of a DEDP in time, social behaviour of a project team, and the influence of the environment. Fine grained and complete knowledge of a process is the central asset which allows PSI methodology be convincing and produce grounded assessments. This knowledge is formalized using the Suite of PSI Ontologies which form a logically sound descriptive theory of the Domain (engineering design in microelectronics) [Er06a]. Indeed, if someone intends to imagine an arbitrary process of designing something, most certainly he or she will think in terms of: (i) a goal – the state of affairs to be reached; (ii) an action, which may bring the process closer to its goal; (iii) an object to apply actions to; (iv) a designer who acts and applies actions to objects; (v) an instrument to be used by an actor to execute actions; and (vi) an environment in which the process occurs.

The structure of the PSI Ontologies Suite reflects this approach. Its core comprises four tightly linked major ontologies: the Actor Ontology (a designer), the Project Ontology (an environment), the Task-Activity Ontology (an action), and the Design Artifact Ontology (a goal and an object). The extensions developed in cooperation of PSI and PRODUKTIV+[3] projects are: Design Artifact Quality and Complexity Ontologies,

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[3] Reference System for Measuring Design Productivity of Nanoelectronic Systems (PRODUKTIV+) is the project partially funded by German Federal Ministry of Education and Research (http://www.edacentrum.de/produktivplus)

actor's Ability Ontology and the Generic Negotiation Ontology [EK06]. PRODUKTIV+ contributions are the Ontology of Resources and the extension focused on a Design Process Character. The current version of PSI and PRODUKTIV+ Ontology Suite is v.1.6 [Er06b].

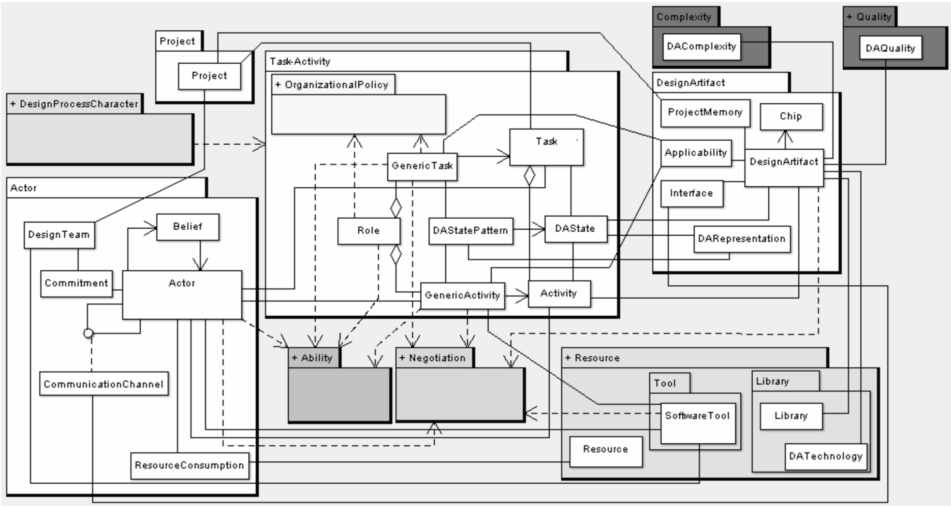

Fig. 1. The high-level structure of the PSI and PRODUKTIV+ Ontologies Suite v.1.6. White packages represent the Core. Colored packages are the Extensions

Our ontologies are used not only to formally describe the Domain of Discourse – a model of a Design System which executes several concurrent DEDPs, but also: (i) to provide soundly defined unified (standardized) lexicon for project partners and the emerging community of early adopters; (ii) to structure the knowledge base of acquired design process knowledge [So06] used in performance assessment experiments; (iii) as the backbone of the prototype software tool under development [Go06]. Due to the ways the ontologies are used it is extremely important to ensure that PSI Ontologies Suite is accepted by the community of experts in engineering design. A common way to ease up the commitment of Domain experts to an ontology is to align its statements with a Domain theory prevailing in the Domain. However, to the best of our knowledge, there is no a "golden standard" ontology in microelectronic engineering design against which our Suite may be evaluated. Therefore, we took a different way to find out if PSI Ontologies Suite is acceptable by the community of experts. The intuition behind our approach is as follows. If an ontology maps smoothly to a sound foundational ontology then we may expect that the statements of our ontology may be accepted by the community because it does not contradict to their intuitive feeling of the semantics of the world – to their common sense.

In order to perform such a mapping in a rigorous manner we had to carefully choose the targets (Section 3) and to provide the upward cotopies [MS02] of our ontology concepts to make the mappings more grounded. For the latter reason we have developed PSI Meta Ontology – the meta-layer of PSI Ontologies Suite. The concepts of PSI Meta Ontology are shown in Fig. 2.

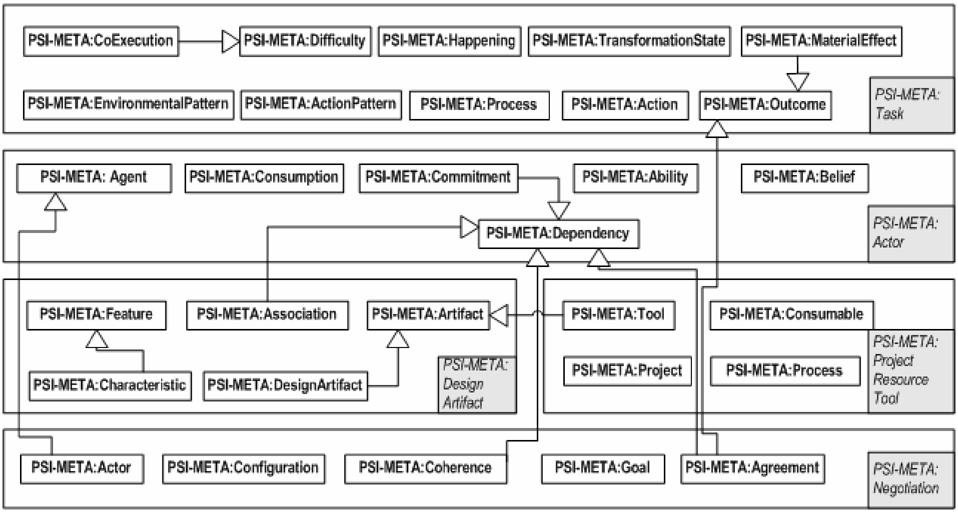

Fig. 2. Concepts of PSI Meta-Ontology

3 Foundational and Common Sense Ontologies

"Scientific theories represent compartmentalized knowledge. In presenting a scientific theory, as well as in developing it, there is a common-sense pre-scientific stage. In this stage, it is decided or just taken for granted what phenomena are to be covered and what is the relation between certain formal terms of the theory and the common-sense world." (c.f. [Mc90]). Therefore, a Domain ontology **has to** be well aligned to the common sense[4]. Common sense theories are formalized in upper-level or foundational ontologies. Today's efforts in establishing foundational ontologies are focused on disambiguation of abstract concepts meaning. Alignment of newly developed ontology with knowledge presented in a small set of foundational ontologies provides wider ontological commitment and facilitates acceptance of the new ontology within the community.

The survey of upper-level ontologies [Ob06] enumerates the following foundational ontologies: Basic Formal Ontology (BFO), a Descriptive Ontology for Linguistic and Cognitive Engineering (DOLCE), Object-Centered High-Level Reference Ontology (OCHRE), OpenCYC, and Suggested Upper-Level Ontology (SUMO). The comparative study of contents of ontology library (consisting of DOLCE, BFO and OCHRE), provided in the frame of WonderWeb [WonderWebD18] project, and SUMO ontology, provided in the frame of Standard Upper Ontology initiative (SUO) has shown that it is

[4] McCarthy meant that scientific theories do not emerge in vacuum. Instead, the primary motivation to devise a scientific theory is the desire to describe the (common) views of different people on a matter of societal interest in a systematic and rigorous manner. Indeed, it lasted for ages that in theory Earth was flat and stood on three whales. Luckily, common sense collection and analysis as a pre-scientific stage in the development of a theory, may supply us with facts that change conceptions. For example, at the moment we consider that Earth is not flat as a valid scientific theory. However, who knows if it is the truth in the last instance ...

unnecessary to align PSI Meta ontologies with all of them. Only two foundational ontologies – SUMO and DOLCE – reflect common sense knowledge about domains, described in PSI Ontologies: tasks and projects, organizations and collectives, material artifacts.

WordNet lexical database [Fe98] was chosen to provide the link from PSI concepts to their natural language semantics. WordNet has strong relationships with formal upper level ontologies, providing generally agreed sense of upper-level concepts.

The SUMO (Suggested Upper Merged Ontology) [NP01] is the work-in-progress carried out by the IEEE Working Group P1600.1 and aimed at the development of the Standard Upper Ontology (SUO). SUMO was created by merging several publicly available ontologies including OpenCYC[5], ontologies from Ontolingua[6] server and others[7] to single, comprehensive and cohesive ontology. SUMO provides a foundation for middle-level and domain ontologies.

SUMO has benefited from its merge and harmonization with WordNet. In 2003 [NP03] all noun synsets in WordNet have received the mappings to SUMO concepts. Those SUMO concepts which have the mappings from WordNet, are in fact enriched with natural language information. SUMO was initially encoded in SUO-KIF[8], the first-order language, based on KIF and enriched with basic SUMO concepts. However, for the purposes of PSI we used OWL encoding of SUMO[9].

DOLCE (Descriptive Ontology for Linguistic and Cognitive Engineering) [Ga02] "aims at capturing the ontological categories underlying natural language and human commonsense". It may be used separately of or together with other modules of foundational ontology library [Ma03], or with OntoClean methodology of ontology verification and disambiguation. DOLCE itself is refined using OntoClean: its concepts hierarchy is checked against the proper preservation of ontological properties.

The history of DOLCE relationships to WordNet is different from that of SUMO. DOLCE has been used as a foundational theory which helped "sweeten" WordNet [GNV03]. WordNet noun system was formalized and rearranged according to DOLCE. OntoWordNet project database is in certain sense more ontologically verified and harmonised in difference to the "raw" original WordNet.

DOLCE-Lite+[10], DOLCE encoding in OWL, provides reduced (due to the limitations of OWL) formalization of this foundational ontology. DOLCE-Lite+ is organized as the network of smaller ontologies, imported by the main DOLCE-Lite+ ontology, *dol*. The network includes ontologies such as: Extended Descriptions and Situations (*edns* namespace), Common Sense Mapping (*common* namespace), Systems (*sys* namespace),

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[5] OpenCYC home page: http://www.opencyc.org/
[6] Ontolingua home page: http://www.ksl.stanford.edu/software/ontolingua/
[7] The list of all relevant content is published on http://suo.ieee.org/SUO/Ontology-refs.html
[8] SUO-KIF details can be found at http://sigmakee.cvs.sourceforge.net/*checkout*/sigmakee/sigma/suo-kif.pdf
[9] SUMO.owl available at http://www.ontologyportal.org/translations/SUMO.owl.txt
[10] DOLCE-Lite+ is available at http://www.loa-cnr.it/ontologies/DLP_397.owl

Collections (*coll* namespace), Collectives (*colv* namespace), Information Objects (*inf* namespace), Plans (*pla* namespace), and others.

Summarizing the review, it is worth saying that WordNet enriches the semantics of SUMO, providing correspondence between formal notions of a Domain, given in SUMO, and its extent, given as natural language descriptions. DOLCE, on the contrary, is constructed without assistance of WordNet, has different naming conventions and is used without WordNet.

4 Mapping PSI Ontologies to the "Golden Standard of Common Sense"

The process of ontology mapping was separated into two independent tasks: mapping to SUMO, and mapping to DOLCE. It was especially interesting to compare mappings, as far as SUMO and DOLCE have different origins and focuses.

Mapping to SUMO has required first to construct missing elements in the upward cotopies of those concepts of PSI Ontologies Suite, which were not generalized in PSI Meta ontology. This task was done with the help of WordNet. For each PSI-Meta concept the mapping to WordNet was done manually, following most appropriate senses and glosses of the word, naming the chosen PSI-Meta concept. Then, following established [NP03] WordNet+SUMO links, correspondent SUMO concepts were obtained. KSMSA Ontology Editor[11] was used as the software tool to perform this part of work.

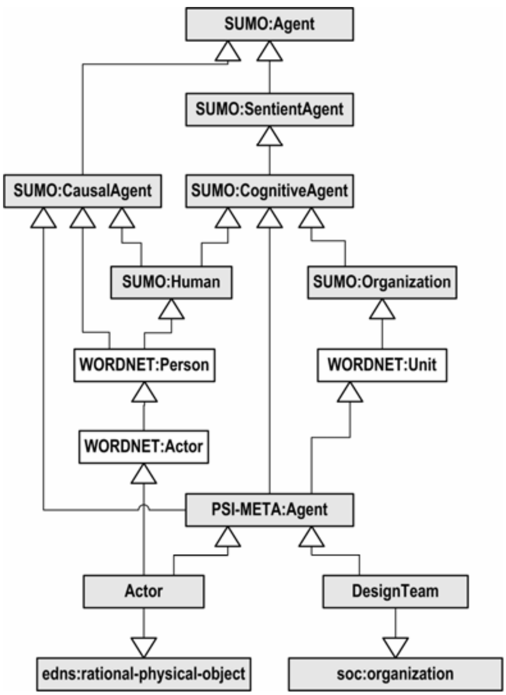

Fig.3. The mapping of concepts *Actor* and *DesignTeam*.

Mapping to DOLCE was performed based on the natural language description of DOLCE concepts. In this part of mapping work WordNet was not used as the mediator due to following reasons: (i) WordNet was analysed with DOLCE [GNV03]; and second – it was interesting to see the differences in mapping with and without WordNet bridge.

[11] KSMSA Ontology Browser is available at http://virtual.cvut.cz/ksmsaWeb/browser/title

Evaluation of PSI DesignArtifact ontology has shown that it maps very well both to DOLCE and WordNet+SUMO. All its concepts received subsumption mappings to common sense. *DesignArtifact* (a goal of a design process and an object transformed by activities) was mapped to *sys:system-as-description*, reflecting the fact that at each stage, from informal textual description to GDSII-file every design artifact is the description of some system. *Chip* (materialization of a design artifact in silicon) was mapped to *sys:design-object-materialization*. Various features of a design artifact, from its type to its complexity and parameters, were mapped to concept *edns:parameter*. The Concept of *Library* of design artifacts in different representations was mapped to *coll:information-collection*. *Applicability* of activity to design artifact was mapped to *edns:modal-description*.

PSI Actor ontology mapping has shown the maturity of the Domain itself. The conceptualisation of an Actor and related concepts in PSI is close to the common sense described both in SUMO and DOLCE ontologies. *Actor* and *DesignTeam* as possible performers of an activity are mapped to DOLCE *edns:rational-physical-object* (*SUMO:Human*) and DOLCE *soc:organization* (*SUMO:Organization*). PSI-Meta concept *Agent*, generalizing both *Actor* and *DesignTeam*, is mapped to *SUMO:Agent* via *SUMO:CognitiveAgent*, generalizing *SUMO:Human* and *SUMO:Organization*. Fig.3 shows correspondent mapping. *Belief* and *Abilities* of Actors were mapped to DOLCE *edns:cognitive-modal-description*, and to *SUMO:Knows* via *WordNet:Ability*. *Commitment* Actor has to obey is mapped to DOLCE *mod:commitment* and to the concept *Cooperation* from SUMO.

For PSI Ontologies Suite two mappings were made: first (or direct) mapping was made for particular ontology from PSI Ontologies Suite into WordNet+SUMO, and separately into DOLCE. Second mapping was made from PSI-Meta ontology into WordNet+SUMO, and separately into DOLCE. Resulting direct mappings (see Table 1) were then subjected to cross-analysis in order to assess the relative quality of mappings to SUMO and to DOLCE. Mappings of PSI-Meta to WordNet+SUMO and to DOLCE are constructed as intersections of mapping results obtained from direct mappings.

Direct mapping results for PSI Ontology. Table 1.

PSI Ontology concept	**PSI Meta concept**	**Mapping to WordNet**	**Mapping to SUMO**	**Mapping to DOLCE**
Task ontology				
Task	Process, Action	Job	IntentionalProcess	pla:complex-task OR pla:elementary-task
Activity	Action	Action	IntentionalProcess	pla:elementary-task
PreCondition	Happening	Prerequisite, Event	Precondition	edns:parameter
PostEffect	Happening, MaterialEffect	Consequence, Event	Physical, Process	edns:parameter
Influence	Happening	Event	Process	edns:parameter
Policy	ActionPattern	PlanOfAction	Plan	mod:commitment
GenericTask		Practice	SubjectiveAssessment Attribute	pla:complex-task OR pla:elementary-task

PSI Ontology concept	PSI Meta concept	Mapping to WordNet	Mapping to SUMO	Mapping to DOLCE
Generic Activity		Practice	SubjectiveAssessment Attribute	pla:elementary-task
Generic Precondition	Environment Pattern	Pattern	DeonticAttribute	edns:parameter
Generic PostEffect		Pattern	DeonticAttribute	edns:parameter
DAState Pattern		Pattern	DeonticAttribute	edns:parameter
Difficulty Type	Difficulty	Quality	Attribute	dol:quality
Execution Relation	Dependency	Relation	Relation	edns:relation
Actor ontology				
Actor	Agent	Actor	CognitiveAgent	edns:rational-physical-object
DesignTeam		Organization	Organization	soc:organization
Resource Consumption	Consumption	Consumption	Decreasing	dol:process
InvolvmentIn GDElement	-	Engagement	IntentionalProcess	dol:process
Commitment	Commitment	Commitment	Cooperation	mod:commitment
Communicatio n Channel	Dependency	Media	Instrument	inf:communication-method
Belief	Belief	Belief	Proposition	ends:cognitive-modal-description
Ability	Ability	Ability	InheritableRelation	ends:cognitive-modal-description
AbilityWrt Task		Ability	InheritableRelation	ends:cognitive-modal-description
AbilityWrt Activity		Ability	InheritableRelation	ends:cognitive-modal-description
DesignArtifact ontology				
Chip	-	Chip	Device	sys:design-object-materialization
Design Artifact	DesignArtifact	Artifact	Artifact	sys:system-as-description
Project Memory	Artifact	Repository	Artifact	coll:information-collection
Project Memory Element		-	Artifact	dol:endurant
Library		Library	Collection	coll:information-collection
Applicability	Dependency	Applicability	BinaryRelation	ends:modal-description
AssociatedTo Design Artifact	Association, Dependency	-	Relation	ends:modal-description
Interface	-	Interface	Device	sys:system-as-description

PSI Ontology concept	PSI Meta concept	Mapping to WordNet	Mapping to SUMO	Mapping to DOLCE
DAParameter	Characteristic	Parameter	Attribute	ends:parameter
DA Representation	Feature	Form	Attribute	ends:parameter
DA Complexity		Complexity	Attribute	ends:parameter
DA Technology		Technology	Attribute	common:measurement-unit
DAType		Type	Subclass	ends:parameter
Project ontology				
Project	Project, Process	Undertaking	IntentionalProcess	edns:course
Resource	Consumable	Resource	Resource	dol:endurant
SoftwareTool	Tool	Tool	Instrument	inf:formal-system
Negotiation ontology				
Negotiation Process	Process	Negotiation	Cooperation	dol:process
Negotiation Goal	Goal	Goal	Proposition	pla:goal-situation
Negotiation Outcome	Agreement	Phenomenon	AsymmentricRelation	ends:situation
Negotiation Party	Actor, Agent	Actor	CognitiveAgent	edns:rational-agent
Negotiation Issue	Characteristic	Issue	Proposition	dol:non-physical-object
Negotiation Set	Configuration	Set	IntentionalRelation	coll:non-physical-collection
Negotiation Protocol		Protocol	DeonticAttribute	inf:communication-method
Negotiation Mechanism	Configuration	Mechanism	IntentionalProcess	edns:method
Negotiation Role	ActionPattern	Role	DeonticAttribute	sem:communication-role
Goal Coherence	Coherence	Coherence	SubjectiveAssessment Attribute	edns:modal-description
Negotiation Type	Characteristic	Type	IntentionalProcess	edns:parameter
Permissible Participant	Agent	Participant	CognitiveAgent	edns:rational-agent
Interaction State	-	State	InheritableRelation	sys:system-as-situation
ValidAction	-	Legal Action	LegalAction	pla:action-task
State Transition Event	-	Event	Process	dol:accomplishment
Communi-cative Act	-	Act	IntentionalProcess	sem:communication-situation
Reward Structure	Configuration	Structure	InternalAttribute	col:parametrized-collection
UtilityChange	-	State change	StateChange	dol:event

As shown in Table 1, the quality of mappings is not distributed evenly:

- A principal difference between (*Generic*)*Task* and (*Generic*)*Activity* is not reflected neither in WordNet, nor in SUMO, but is easily resolved in DOLCE: tasks are complex or elementary portions of work, but activities are elementary only
- *GenericPrecondition*, *GenericPostEffect* and *DAStatePattern* are mapped to WordNet noun *Pattern*, and then in SUMO – to *DeonticAttribute*, whereas in DOLCE they are correspondent to rather abstract *edns:parameter*
- Actor's *Ability*, *AbilityWrtTask*, *AbilityWrtActivity* are mapped to abstract *SUMO:Relation*, but DOLCE correspondent *ends:cognitive-modal-description* reflects semantics of abilities more precise
- *NegotiationProcess* is mapped to *SUMO:Cooperation*, a kind of *SUMO:IntentionalProcess*, but in DOLCE *NegotiationProcess* is simple *dol:process*

Another observation concerns the fact that for both mappings to SUMO and to DOLCE WordNet greatly facilitates the work with concepts, having several senses. At the same time, the usage of WordNet does not automate the decision taking on the sense of each concept from PSI Ontologies Suite. Even if the name of the concept is presented in WordNet, the meaning of every concept evaluated separatel. A designer should first take into account the context of the concept and then find suitable WordNet synset. If the name of the concept is not known to WordNet/SUMO/DOLCE (see e.g. *DA:ProjectMemoryElement*, *DA:ApplicableToDA*), then the mapping is really performed in the "expert-driven" manner, without any lexical support from WordNet.

Mapping results can also serve as demonstration of focuses of SUMO and DOLCE. All concepts in SUMO are on the very top divided onto abstract and physical, relations, imposed on concepts are either objective or subjective (intentional, assuming there is an agent, aware of that concept). SUMO includes possibly most elaborated collection of various processes – 48 classes [NP01]. Tight relationship with WordNet and non-ontological style of concept names substantially eases the work with SUMO.

DOLCE on the very top is also divided into spatio-temporal particulars and abstract particulars. Spatio-temporal particulars are divided into endurants and perdurants, implicitly involving time into ontological analysis. On the subsequent levels of hierarchy, however, distinction between abstract and non-abstract concepts in several situations has been made explicitly, introducing certain complexity of perception.

5 Related Work

Horizontal alignment and mapping between similar ontologies of a domain is investigated by many research groups. The methods to obtain suitable mapping range from semi-automated mapping tools [Bi05] to lexical matching [NM02], context-aware matching [Bo03], statistical instance-oriented matching [Do03] and similarity-based mapping [ES05]. Most works dedicated to the horizontal alignment and mapping of similar ontologies: different ontologies of tasks and plans, of social collectives, ontologies in bioinformatics, see, e.g. [WAP05]. However, to the best of our knowledge, the Domain of Engineering Design Processes doesn't have other ontologies describing its details. Therefore, horizontal alignment and mapping methods mentioned above do not fully applicable to our Domain.

Additionally, and it is emphasized in [Ro05], the quality of ontologies evaluated in that way, is not high, and the mapping results are disappointing, though they are of great importance. To overcome this drawback, in several domains, mostly in bioinformatics the efforts of ontology engineers are specially focused on vertical alignment – through mid-level reference ontologies like OBR (Ontology of Biomedical Reality) with high-level ontologies, BFO (Basic Formal Ontology) and FMA (Foundational Model of Anatomy) describing most abstract concepts of the bioinformatics domain. The research on vertical alignment relies heavily on sound ontological principles, such as the ones of unity, rigidity, essence and dependence, used in OntoClean [GW01]. Application of OntoClean to PSI Ontologies Suite is planned for the further research in PSI.

Standing separately Deontic Pattern Analysis [JW98] provides means of deontic logic and pattern analysis for checking the completeness of a Domain ontology, if deontic objects can be found in this Domain. The method has demonstrated its utility for the analysis of business processes modeling languages, the concepts of information systems and in some other Domains. Its usage for evaluation of PSI Ontologies Suite is also of great interest.

6 Concluding Remarks

The results of common sense mapping of PSI Ontologies Suite are encouraging. Most concepts in ontologies for elaborated Domains, such as Actors, Tasks, DesignArtifacts and Projects are mapped as subclasses to the concepts of the mid-level of foundational ontologies. This reflects the real common sense orientation of PSI Actor, PSI Task and PSI DesignArtifact ontologies: their structure might be well accepted by the community, and the anticipated ontological commitment with respect to these ontologies is more or less stable.

PSI Meta ontology unifies PSI Ontologies family, providing generalizations for similar concepts from different PSI ontologies from one point of view, but it does not help much for mapping purposes. Instead, the presence of meta-ontology is the starting point to compare it to the known deontic patterns, and to check if all elements of some pattern are used in meta-ontology. The paper did not focus on deontic analysis of PSI Ontologies but it is planned for future research.

PSI Negotiation ontology describes a relatively less elaborated Domain from the ontological perspective. It has received its evaluation with respect to the common sense. Despite the fact that a negotiation process is a kind of cooperation (according to SUMO mapping), it might be argued that negotiation deserves more attention with respect to common sense. Indeed, cooperation is a joint coordinated activity of multiple parties aiming to their coherent goals. Negotiation has a different semantic scent. It is a process of reaching an agreement on the goals which may only become coherent in the future –

when the agreement is reached. Our perception is that both WordNet+SUMO and DOLCE are underdeveloped in their parts covering agreements. Further refinement of these foundational ontologies may therefore be desired.

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