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A Method for Collaborative Argumentation in Merging Individual Ontologies

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Abstract: This paper proposes a framework of the negotiation process for solving divergences in the collaborative ontology development. Such framework is obtained through the use of philosophical principles deriving from the theories of essence, identity, unity and dependence (preconized by the OntoClean methodology) as to justify part of the argumentation used in the negotiation process among the participants, besides helping reach a consensus and reduce the conceptual gap among models. The evaluation of the experiments conducted with the use of the proposed method suggests the feasibility and implementability of our approach in practice.

Keywords: collaborative ontology development, negotiation process, argumentation, OntoClean, conceptual gap.
Categories: M.0, M.4, M.9

1 Introduction

The development of ontologies is a social process, whose objective consists in producing a conceptualization shared by a group of people in a specific domain [Guarino et al. 09]. Conceptualization, in its turn, is a subjective activity, comprising the various ways in which individuals perceive a particular reality to be represented. Abstracting some aspects of such reality results in intended models, which include concepts, relations, and objects of the domain meant to be represented [Guizzardi 05].

The representation of the intended model (present in the individual's mind) is done through the use of a language, thus producing a concrete artifact: the model specification, i.e., in this work, the ontology. However, due to expressiveness limitations concerning languages [Guarino 09] and human beings [Heep 07], such representation might not be totally correct[1], resulting in a conceptual gap [Thalheim 10] between the intended model and the specified model.

As a consequence of the increasing use and size of ontologies, there has been a change in the ontology development process. While it was traditionally carried out in a centralized, isolated way by ontology modelers (capturing the knowledge of the domain experts), it has now shifted to a geographically distributed collaborative

[1] A correct representation is a valid structure, which produces inferences corresponding to the intended model.

configuration, in which the development is done by a heterogeneous team playing different roles in the process [Palma et al. 11]. As examples of outstanding ontology projects, we can mention: OpenCyc[2], DOLCE[3], PROTON[4], SNOMED-CT[5], ICD[6], GO[7] e OBO[8].

In the collaborative ontology development process, individual ontologies can be separately developed since the beginning, adapted or specialized from a copy of the main ontology, subdivided into sub-ontologies of the main ontology modified by distributed users or into a single core copy modified by all participants. In all cases, the merging of all updates on the individual ontologies will be done so as to form a single collaborative ontology describing the participants' consensus regarding the representation of a specific domain.

Divergences arise from the merging of individual ontologies as a result of the different conceptualizations participants have regarding the domain. Such divergences are usually solved through negotiation processes, in which the participants argue in order to advocate their individual ideas until they reach consensus on the solution to be adopted.

Approaches that use argumentation to support the negotiation process usually make use of informal arguments, once they are based on tacit knowledge acquired by the participant's personal experiences. In this way, it is difficult to be formalized and spread, given its relation to specific knowledge acquired at a specific time and space [Nonaka et al. 00]. The more the argumentation is based on personal experiences or interests of the participants, the higher is the risk that the ontology diverges from the intended model. Consequently, the harder is to achieve the ontology correctness so the existing modeling problems must be reviewed and corrected in subsequent stages, increasing the ontology's development budget and, in case problems are not repairable, even hampering its use.

This paper proposes the argumentation formalization as a way to support, facilitate, and serve as basis of the negotiation process for solving divergences in the collaborative ontology development. Formalization takes place through the employment of philosophical principles based on the essence, identity, unity and dependence theories preconized by the OntoClean methodology [Guarino and Welty 04] to justify part of the arguments used in the negotiation process and "formalize" them. Those arguments are called "formal" because they provide a justification for the modeling choices regardless the domain as well as pointing out the existing inaccuracies in the modeling.

By providing the basis for the participants' decisions, the effectiveness of the negotiation process is improved, given the fact that even experienced modelers are frequently unable to justify their modeling heuristic choices and that divergences found can be solved only with justifications deriving from philosophical principles, thus characterizing relevant aspects of the interpretation meant to the elements that

[2] http://www.cyc.com/cyc/opencyc/overview
[3] http://www.loa.istc.cnr.it/DOLCE.html
[4] http://proton.semanticweb.org/
[5] http://www.ihtsdo.org/snomed-ct/
[6] http://www.who.int/classifications/icd/en/
[7] http://www.geneontology.org/
[8] http://obofoundry.org/

form the ontologies [Guarino and Welty 04]. Consequently, the reduction of the conceptual gap is expected by approximating the intended model and the specified model, since developers are led to think and reflect on what they really intend to represent so as to guarantee a consistent interpretation of the ontology elements.

Although the OntoClean methodology is widely accepted by the scientific community, its application is still considered burdensome and hard to understand. Indeed, even experienced ontology modelers share such view [Völker et al. 08].

Aiming to minimize the OntoClean usability problem, the methodology was integrated into a collaborative argumentation process, creating a transparent method for the user. To do so, a template basis was used to provide cues for the participants regarding the assignment of OntoClean metaproperties and validation of the ontology hierarchy. Such templates are based on the philosophical framework that guide the metaproperties principles and the constraints imposed by them, thus aiming to facilitate the understanding of the OntoClean and reducing the participant's cognitive load.

The next sections of this document are organized as follows: Section 2 presents the introductory concepts on the OntoClean methodology. Section 3 deals with the aspects regarding the negotiation and argumentation process. Section 4 specifies the proposed method, the Method for Collaborative Argumentation in Merging Individual Ontologies (CAMIO). Section 5 brings the experiments conducted for evaluating the CAMIO and the results achieved. The related works are presented in Section 6, while conclusions are found in Section 7, and finally, future works in Section 8.

2 OntoClean Methodology

The OntoClean methodology is based on general ontological notions drawn from Philosophy. Those notions are used to characterize relevant aspects of the meaning intended for the elements that constitute an ontology, making modeling arguments explicit and revealing their logical consequences [Guarino and Welty 04]. In addition, OntoClean helps evaluate and validate the modeling by imposing constraints on the ontology's hierarchy of concepts.

Some basic definitions are important for the correct understanding of the OntoClean terms. Firstly, OntoClean authors adopt the model-theoretic semantics to define its metaproperties. Informally, modal logic is employed to perform the formalization of such metaproperties, and thus they are defined through a structure of possible worlds. A world is populated by individuals that hold or instantiate properties. In this way, it is possible to define concepts, i.e., a set of individuals that share the same properties, and in which worlds they occur.

Concepts are organized under a subsumption hierarchy in which more general concepts (superconcepts) subsume more specific concepts (subconcepts) so that more specific concepts inherit the properties of the more general ones.

2.1 Essence and Rigidity

Rigidity is based on the notion of essence. A property is essential if its set of individuals is unchangeable in all possible worlds, that is, all individuals hold the property in all possible worlds. For instance, individuals that instantiate the property *being _human* will be human in all possible worlds in which they exist, that is to say the property *being_human* is rigid.

Essence occurs in varied ways, represented by the notion of rigidity:

1-) Rigid: is an essential property for all individuals, i.e., an individual that instantiates a rigid property cannot fail to instantiate it in all possible worlds of which the individual exists.

2-) No-rigid: a property is no-rigid if an individual instantiates it in some of the possible worlds, but fails to do it in other possible worlds.

2.2 Identity

Identity concerns the capacity to recognize whether one individual of a concept is different from the others individuals of the same concept by some specific characteristic that is unique for it [Guarino and Welty 01b]. Identity criteria allows one to recognize an individual as being the same, at any time, and in any possible world, once the concept holds some identity criteria.

2.3 Unity

Unity concerns the capacity to distinguish the parts of an individual from the rest of the world by means of a unifying relation that connects them, not involving any other instance. Units may also include parts that are, in their turn, other units ruled by different unifying relations.

2.4 Dependence

The notion of dependence distinguishes properties between extrinsic and intrinsic, relating individuals with their subjection or not to other individuals of other concepts.

Intrinsic properties are inherent to the individual, such as *having_heart* or *having_fingerprints*.

The dependence is based on extrinsic properties, which are not inherent to the individual and have a relational nature with other individuals, which are neither part of it nor its constituents.

2.5 Subsumption Constraints

OntoClean is also employed to evaluate and validate the subsumption hierarchy of the concepts. When violations of the subsumption constraints occur, they normally account for inadequate built or misunderstood taxonomies. In this way, corrective actions include reconsidering the concept meaning (its conceptualization), or develop a new assignment of other metaproperties in order to guarantee consistency, or even change the concept position in the hierarchy.

In the subsumption hierarchy, *a no-rigid property cannot subsume a rigid property*. For instance, the concept *student* is no-rigid, as individuals can stop holding the property *being_student*. The concept *human* is rigid, given that once an individual is human can´t stop *being_human.* In this way, it is incorrect that the concept *student* subsumes the concept *human*, since it implies in humans necessarily being students. That is to say, if a student stop being student he would likewise stop being human, contradicting the assumptions determined in the human being conceptualization.

A property that comprises identity criteria cannot subsume a property that does not comprise such criteria. That is because individuals of the most specific concept cannot be identified, even when they inherit the identity criteria of the most general concept. For example, the concept *human* comprises fingerprints as an identity criterion, so the concept *student*, subsumed by the concept *human*, inherits fingerprints as an identity criterion.

A property that does not have unity criteria cannot subsume a property that comprises such criteria. For example, if the concept *ocean* is subsumed by the concept *water*, a contradiction takes place. In this case, individuals from *water* do not comprise unity criteria, once they are sparse, disperse and no delimited substances. On the contrary, individuals from *ocean* comprise unity criteria, once the limits of the oceans are known and it is possible to determine what is and what is not part of them.

A dependent property cannot subsume a non-dependent property for dependence is transferred to the subsumed properties. For example, *teacher* cannot subsume *human*, once all teachers have a dependence relation with an education institution. Such dependence, however, does not make sense to all human beings, causing a hierarchical inconsistency.

3 Negotiation Process and Argumentation

Knowledge building within a collaborative process demands that knowledge representations are shared among the participants and that the participants are somehow able to argue about the differences found until they proceed towards reaching a consensus or making a final decision regarding a conceptualization.

The main advantage of collaboration consists in increasing the quality of the solution, once the merging of diverse member perspectives and, consequently, their employment, causes the decision to be less subjective than the decision of a single person, and thus represent a consensual view of the domain [Karapiperis and Apostolou 06].

The collaborative development of ontologies is an application that inherently requires a negotiation process in order to solve differences among individual ontologies through the collaboration/negotiation among the participants.

A collaboration/negotiation process can be developed in three stages [Linhares et al. 09]:

- Proposal submission: participants submit proposals to solve the problems presented.
- Negotiation based on argumentation: participants have to come to common terms regarding each proposal. Communication is necessary to confront individual points of view, which may either be favorable or against the proposal, besides providing arguments to uphold the positions adopted.
- Decision: once common terms are achieved, a decision must be made. This stage includes analyzing the implications of the adopted solution and the subsequent stages needed to put it into practice.

All participants must review all proposals so that the solution adopted fulfills the requirements. Among the main rules that can be defined for counting individual positions, the most common in the collaborative ontology development are: majority rule (the most voted proposal is chosen), consensus (only one result corresponds to the position of all participants), and moderation (a moderator must decide the result according to the positions of the participants).

In most approaches that deal with collaborative ontology development, the social process involving collaboration and negotiation in the creation of a shared conceptualization is not given much importance [Pereira et al. 08], and thus there is no specific method or technique available to its application. The social process is normally supported by forums or e-mail discussion lists, which provide storage capacity and history. Discussions, alternatives considered, and decisions made are, however, usually not directly related to the specific elements to which they refer, and are not directly accessible for the ontology, hampering the search and correlation of the discussions with the ontology content [Noy and Tudorache 08].

There are some tools, which provide the ability to add argumentation to the evolution of the ontology, in order to reach consensus or to discuss issues. In Collaborative Protégé [Noy and Tudorache 08], users may comment on the ontology elements, propose and discuss changes, and choose among the proposals submitted. Such comments are associated with the specific elements to which they refer in the ontology, allowing the tracking of the changes proposed and a discussion history. Nevertheless, there are no tools either for conducting the discussions or for transferring the results achieved by the voting.

The Co4 [Euzenat 95] presents a protocol for autonomous agents in a distributed memory context for mediation of the submission of the individual knowledge to the group´s knowledge base. Co4 ensures consistency of individual knowledge by checking redundancies, subsumptions and similarities with the group´s knowledge, without human interaction. The argumentation is started when an individual knowledge is submitted to the group, which may respond by accepting, rejecting or proposing alternatives to it (which will be discussed again). Discussions are conducted using feedback with precise semantic meaning, which are recorded for tracking updates. When the group got enough comments, changes are integrated (or not, in case of rejection) to the group´s knowledge base.

The Cicero argumentation tool [Dellschaft et al 08] allows an asynchronous discussion and decision making process between participants of ontology engineering projects and supports its users in applying the idea of issue based information systems. Also allow the annotation of ontology elements with the corresponding discussion as well as searching the content of discussions. Cicero addresses the need for holding discussion in collaborative ontology engineering as well as change and voting proposals.

4 Method for Collaborative Argumentation in Merging Individual Ontologies (CAMIO)

The proposed method for Collaborative Argumentation in Merging Individual Ontologies (CAMIO) can be used in any negotiation process for solving divergences, regardless the ontology development methodology employed as well as the previous assignment of OntoClean metaproperties.

Alignments of an ontology matching process provide the information used by the CAMIO to seek correspondences among the semantically related elements from different ontologies [Euzenat and Shvaiko 07]. The following information is necessary:

- List of similar elements deriving from individual ontologies.
- Type of the elements mentioned above: concepts, relationship or individuals. The kinds of divergence employed by the CAMIO are:
- Concepts in different taxonomic positions.
- Concepts assignment with different OntoClean metaproperties.
- Violations of the OntoClean constraints on metaproperties in the subsumption hierarchy.
- Relationship with the different domains and images sets.
- Same individual as instance of different concepts.

The process occurs for all elements of the individual ontologies. The CAMIO workflow and its stages are presented in [Fig. 1].

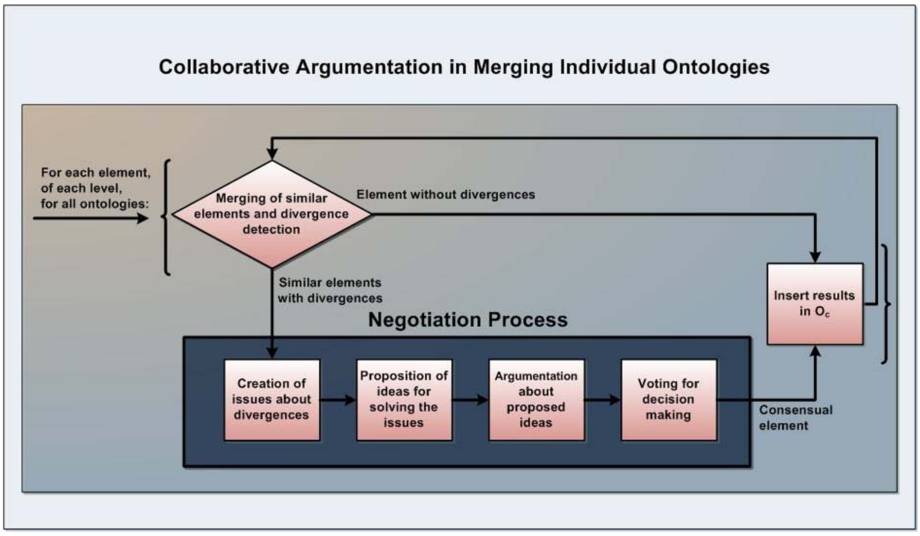

Figure 1: CAMIO Workflow

4.1 Merging of Similar Elements and Divergence Detection

Elements of the individual ontologies Oi are merged to produce a single collaborative ontology Oc. O_c may include most elements of ontologies Oi, though not necessarily all of them, and probably be different from all O_i, once the decisions made reflect the participants' consensus.

The merging process of concepts is done according to the breadth-first search principle, starting the merging with the most general concepts, proceeding with the merging of more specific concepts. By starting with the merging of the most general concepts, which are normally more stable, with a central importance degree and a lower granularity level, the reach of a consensus and the avoidance of backtracking are intended, i.e., unmaking and remaking decisions already made.

[Tab. 1] brings the concept merging algorithm in the O_i. In the first part of the algorithm (lines 1-7), concepts of all ontologies O_i are grouped by level, from level 1 (more general) to level n (more specific), and stored in the ConceptsByLevel vector. In the second part (lines 8-19), all concepts of each level of the ConceptsByLevel vector are obtained. For each concept, similar concepts are searched, and then, the taxonomic positions of the concept and the similar ones are checked as well as its OntoClean metaproperties.

```
Merge(Oi, ..., On) return Oc
Input:    O1, .. , On: individual ontologies;
          A: list of alignment of similar concepts in O1, .. ,On
Output:   Oc: collaborative ontology

P: list of explored concepts

//Grouping of Oi concepts by level
01: For i=1 .. d (maximum depth of O1,..,On)
02:    For j=1 .. n (number of ontologies)
03:       For k=1 .. m (number of concepts of ontology[j] at level[i])
04:           ConceptsByLevel[i] ← Enqueue (ontology[j].label,
                                            ontology[j].concept[k].label,
                                            ontology[j].concept [k].OC)
05:       End_For
06:    End_For
07: End_For

//Search similar concepts in Oi, then check their taxonomic position and OC metaproperties,
and according to the results start (or not) a discussion process.
08: For i=1 .. d
09:    While ((C ← (Dequeue(ConceptsByLevel[i]))) is not empty) and (C is not in P) Do
10:        Similars ← Search Similar Concepts(C, A)
11:        Case ((Same Taxonomic Positions(Similars)) is true) and
                ((Same OC Metaproperties(Similars)) is true) Then
12:                Update Oc with (C)
13:        Case ((Same Taxonomic Positions(Similars)) is true) and
                ((Same OC Metaproperties(Similars)) is false) Then
14:                OC_Results ← Negotiation Process About OC Metaproperties(Similars)
15:                Update Oc with (C, OC_Results)
16:        Case (Same Taxonomic Positions(Similars)) is false Then
17:                TX_Results ← Negotiation Process About Taxonomic Position(Similars)
18:                OC_Results ← Negotiation Process About OC Metaproperties(Similars)
15:                Update Oc with (TX_Results, OC_Results)
16:        Add C to P
17:     End_While
18: End_For
19: Return Oc
```

Tab1e 1: Concept merging algorithm in the O_i

There are three possibilities for treating concepts and divergences:

1. Similar concepts are in the same taxonomic position in the O_i and hold the same OntoClean metaproperties, then the concept is directly included in the O_c.

2. Similar concepts are in the same taxonomic position in the $O_{i,}$ but hold different OntoClean[9] metaproperties, then a negotiation process is necessary to reach a consensus regarding the OntoClean metaproperties (stored in OC_Results). The concept and the result in OC_Results are included in the O_c.

3. Similar concepts are in different taxonomic positions in the O_i or the concept exists in a single O_i, then a negotiation process is necessary to reach a consensus regarding the taxonomic position (stored in TX_Results) and the OntoClean metaproperties (OC_Results). Results in TX_Results and OC_Results are included in the O_c.

For example, given a specific execution of the CAMIO with the following input:

- The individual ontologies $\{O_1, O_2, O_3\}$ presented in [Fig. 2 (A)], given $O_1 \neq O_2 \neq O_3$.
- The alignment list of similar concepts in $\{O_1, O_2, O_3\}$ presented in [Fig. 2 (B)].

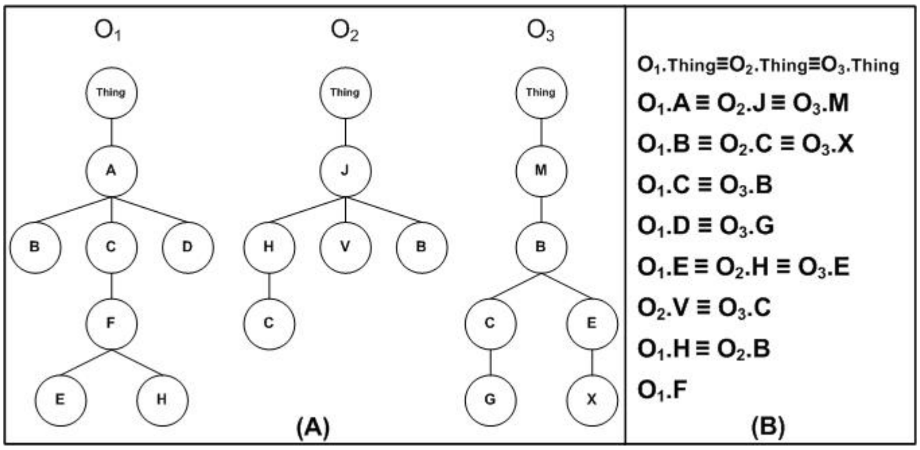

Figure 2: (A) Concepts of ontologies O_1, O_2, O_3. (B) Alignment of similar concepts in the ontologies O_1, O_2, O_3.

The vector ConceptsByLevel is built [Fig. 3], containing concept lists for each level i (d=4) of $\{O_1, O_2, O_3\}$.

For every concept of the list of each level of vector ConceptsByLevel, a search is made so as to find out the similar concepts (line 10) and then compare them to the taxonomic positions and to the OntoClean metaproperties (lines 11, 13 or 16).

A synthesis of comparisons for this example is presented in [Tab. 2]. The column Results brings the comparison results between taxonomic positions (TX) and the OntoClean metaproperties (OC) of the concepts and their similar.

[9] In case there is no previous assignment of OntoClean metaproperties to the concepts existing in the O_i, the method assumes that the concepts hold different metaproperties.

Details of the actions indicated in [Tab. 2] will be described in [Section 4.1] until [Section 4.6].

Level	**Similar Concepts**	**Results**	**Actions**
1	O_1.Thing→level 1 O_2.Thing→ level 1 O_3.Thing→ level 1	= TX = OC	Concept directly inserted in O_C Update O_c with (O_1.Thing,O_c , -I-U+R-D)
2	O_1.A→level 1 O_2.J→level 1 O_3.M→level 1	= TX = OC	Concept directly inserted in O_C Update O_c with (O_1.A, O_c.Thing, +O-U+R-D)
3	O_1.B→ level 2 O_2.C→ level 3 O_3.X→ level 4	≠TX	Negotiation process for TX and OC TX_Results:={O_2.C, O_c.Thing} OC_Results:={-I-U~R +D } Update O_c with (TX_Results, OC_Results)
3	O_1.C→ level 2 O_3.B→ level 2	=TX ≠OC	Negotiation process for OC OC_Results:={+I+U -R-D } Update O_c with (O_1.B, O_c.A, OC_Results)
3	O_1.D→ level 2 O_3.G→ level 4	≠TX	Negotiation process for TX and OC TX_Results:={O_3.G, O_c.C} OC_Results:={+O+U~R +D } Update O_c with (TX_Results, OC_Results)
3	O_2.H→ level 2 O_1.E→ level 4 O_3.E→ level 3	≠TX	Negotiation process for TX and OC TX_Results:={O_3.E, O_c.C} OC_Results:={+O~U~R +D } Update O_c with (TX_Results, OC_Results)
3	O_2.V→ level 2 O_3.C→ level 3	≠TX	Negotiation process for TX and OC TX_Results:={O_2.V, O_c.B} OC_Results:={+O+U~R +D } Update O_c with (TX_Results, OC_Results)
3	O_2.B→ level 2 O_1.H→ level 3	≠TX	Negotiation process for TX and OC TX_Results:={O_1.H, O_c.B} OC_Results:={+I+U-R-D } Update O_c with (TX_Results, OC_Results)
4	O_1.F→ level 3	≠TX	Negotiation process for TX and OC TX_Results:={O_1.F, O_c.Thing} OC_Results:={+O+U+R-D } Update O_c with (TX_Results, OC_Results)
5	Empty	-	Return O_c

Table 2: Synthesis of comparisons of the CAMIO for the example in question.

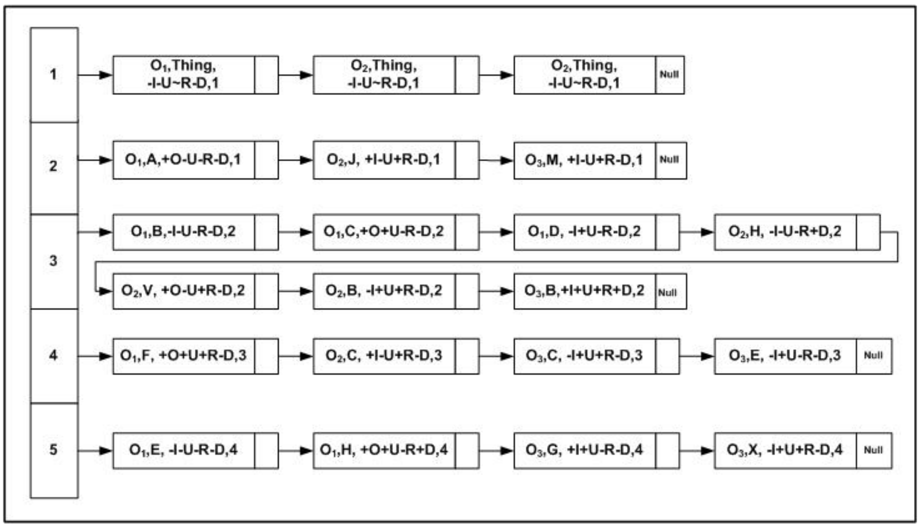

Figure 3: Lists of the vector ConceptsByLevel

The collaborative ontology O_c, as a result of running this example, is shown in [Fig. 4].

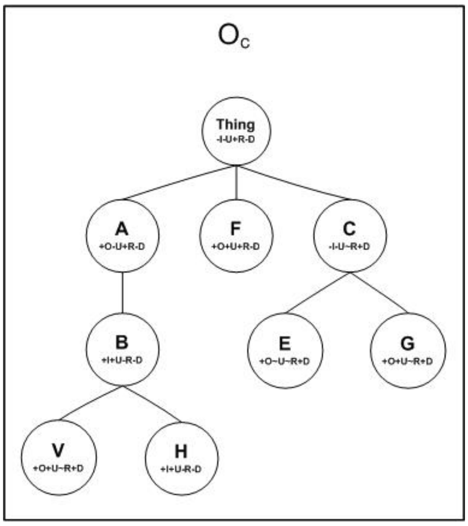

Figure 4: Collaborative Ontology

4.2 Argumentation Structure for the Negotiation Process

The negotiation process is based on an argumentation structure (represented by an ontology) inspired and adapted from the IBIS argumentation methodology (Issue-Based Information System) [Kunz and Rittel 70]. Such structure selects the argumentation types changed and registers the discussion process of all divergences found as well as the decisions made for solving them.

The main elements used in the negotiation processes are: issues, ideas, arguments, among others related to the identification of the participants and the negotiation history. All information exchanged in the negotiation process is registered as a way to support the tracking of a certain decision.

The CAMIO compares the divergences resulting from the merging process of the O_i [Section 4.1] and uses textual templates to organize and control the negotiation process for solving the divergences and proposing the appropriated argumentation elements.

All templates used by CAMIO were designed according to examples found in the OntoClean methodology literature OntoClean [Guarino and Welty 00a], [Guarino and Welty 00b], [Guarino and Welty 00c], [Guarino and Welty 01a], [Guarino and Welty 01b], [Guarino and Welty 02], [Guarino and Welty 04] and then improved with results from the experiments.

The use of the templates aims at employing OntoClean in a transparent way for the user, promoting the understanding of the philosophical principles related to identity, unity, essence, and dependence. In their turn, these principles correspond to the framework required for the use of OntoClean metaproperties as well as promoting the understanding of the results related to the verification of the constraints imposed by the methodology. If the participant considers the proposed template not understandable enough, he may request successive submissions of new templates that deal with the same issue.

In so doing, the entire negotiation process is oriented so as to allow the participants to better understand the logical consequences of each divergence under discussion, to help them reflect on the presumptions done in the domain representation, and to guarantee a consistent interpretation of the ontology elements.

4.3 Creation of Issues about Divergences

Negotiations start with the proposition of issues. Each issue introduces a new topic related to a divergence to be discussed by all participants of the negotiation process.

Issues are automatically created according to textual templates based on the divergence types treated in the CAMIO, presented in the beginning of [Section 4]. Examples of templates used in the proposition of issues are shown in [Tab. 3].

4.4 Proposition of Ideas for Solving the Issues

Ideas are suggestions for solving an issue (divergence under discussion). During negotiations, both the CAMIO and the participants can submit ideas for solving the issues presented.

Divergence	Templates for Proposition of Issues
Identity	There are divergences regarding the identification of the individuals of <*conceptName*>.
Unity	There are divergences regarding the distinction made among the parts and limit of the individuals of <*conceptName*>**.**
Essence	There are divergences regarding the requirement for an individual to be <*conceptName*>, in all possible worlds.
Dependence	There are divergences regarding the external dependences for the existence of the individuals of the concept <conceptName>.
Taxonomic Position	There are divergences regarding the taxonomic position of the concept <*conceptName*>.
Subsumption Constraints	According to the features already assigned, <*conceptName*$_1$> cannot be a subconcept of <*conceptName*$_2$> due to inconsistencies: <inconsistence$_1$,..,inconsistence$_n$>.

Table 3: Examples of issue templates

Ideas are correlated with the kind of issue treated. For example, if the issue deals with a taxonomic position divergence, ideas will suggest the assignment of the concept to other taxonomic positions. If the divergence regards the OntoClean metaproperties, ideas provide assignment suggestions for the OntoClean metaproperties. On the other hand, if the divergence regards the violation of constraints among metaproperties, ideas present the consequences of inserting a concept in a certain hierarchy position and suggest changes in the metaproperties of the concepts involved. [Tab. 4] shows the examples of templates used for automatic proposition of ideas.

Divergence	Templates for Proposition of Ideas
Taxonomic Position	Model <*superconceptName*> as subconcept of <*suboncept Name*>.
Identity OntoClean Metaproperties	Model <*conceptName*> as a concept that have an identification criterion.
Subsumption Constraints	<*subconceptName*> and <*superconceptName*> have different features. Solutions: <*subconceptName*> is subconcept of another **Concept** or <*subconceptName*> and/or <*superconceptName*> have to change their features.

Table 4: Examples of idea templates

4.5 Argumentation of Proposed Ideas

The CAMIO and the participants can provide arguments to demonstrate their position (favorable or unfavorable) regarding any proposed idea for solving the issues found in the O_i. Favorable arguments reinforce an idea, while counter-arguments undermine it, and thus help users in the decision-making process.

In addition, the CAMIO compares divergent modeling choices and makes use of templates to propose favorable or unfavorable arguments on the ideas being discussed. An example of an argumentation for divergences in identity OntoClean metaproperty is shown in [Fig. 5].

Such arguments may deal, for instance, with the implications of a concept position in the hierarchy. Also, they demonstrate the assignment results of certain metaproperties chosen for the concept as well as present the logical consequences of the metaproperties inherited by a superconcept. [Tab. 5] brings examples of argumentation templates.

4.6 Voting for Decision-Making

The voting process is a mechanism used to measure concrete results of the discussions, i.e., a mechanism through which participants have to choose the best solution for each divergence, a solution that must represent the opinion of most participants.

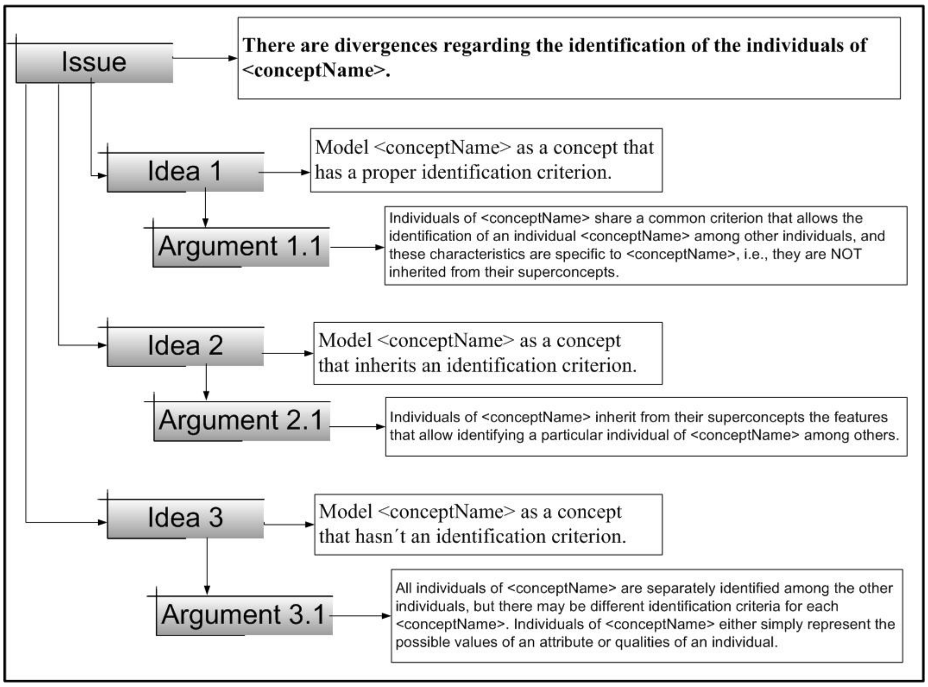

Figure 5: Argumentation for divergences in identity OntoClean metaproperty

Participants express their views on the ideas presented through the CAMIO and through other participants, voting for the idea they consider to be the best solution for solving the issues regarding each divergence found.

The voting process makes use of a plurality system [Vidal 06], [Shoham and Leyton-Brown 09], in which each participant votes for his favorite option only once. Votes are counted and the option with most votes is chosen as the winner solution.

If there is a tie, a new negotiation round is conducted. In this round, however, only the most voted options are available for voting, the options that caused the tie.

Divergence	Templates for Proposition of Argumentations
Supply Identity	Individuals of <*conceptName*> share a common criterion that allows the identification of an individual <*conceptName*> among other individuals, and these characteristics are specific to <*conceptName*>, i.e., they are NOT inherited from their superconcepts.
Carrying Identity	Individuals of <*conceptName*> inherit from their superconcepts the features that allow identifying a particular individual of <*conceptName*> among others.
No Identity	All individuals of <*conceptName*> are separately identified among the other individuals, but there may be different identification criteria for each <*conceptName*>. Individuals of <*conceptName*> either simply represent the possible values of an attribute or qualities of an individual.
Unity	All parts of individuals of <*conceptName*> are delimitable, so it is possible to know exactly what is or what is not part of each individual of <*conceptName*>, and under what conditions each <*conceptName*> is considered complete.
Anti-Unity	Individuals of <*conceptName*>are not whole or complete, because it regards something scattered and dispersed, which can get confused with other individuals of <*conceptName*>.
No-Unity	There are different criteria to determine the parts of individuals of <*conceptName*>, although all individuals have linked parts that form a complete unit, and these parts may themselves be other complete individual units.
Rigid	Every individual that is <*conceptName*> will always be <*conceptName*> in all possible worlds.
Anti-Rigid	Every individual that is <*conceptName*> may stop being <*conceptName*>, according to a certain condition or action.
No-Rigid	There are some individuals that are <*conceptName*> but may no longer be <*conceptName*> in some possible world, while others will always be <*conceptName*> in all possible worlds.
Dependence	In order to belong to <*conceptName*> an individual must have a relationship with other individuals of other concepts.
No-Dependence	Individuals of the concept <*conceptName*> do not depend on the relationship with other individuals of other concepts in order to exist.
Taxonomic Position	Every <*subconceptName*> is a kind of <*superconceptName*>.
Subsumption Constraints	According to the features already assigned, <*subconceptName*> cannot be a subconcept of <*superconceptName*>, due to inconsistencies: • <*Template of OC argumentation of superconcept*$_1$>, otherwise <*Template of OC argumentation of subconcept*$_1$>. • <*Template of OC argumentation of superconcept*$_n$>, otherwise <*Template of OC argumentation of subconcept*$_1$>. Possible solutions: i-) Change the subconcept <*subconceptName*> features, or ii-) Change the subconcept <*subconceptName*> taxonomic position, or iii-) Change the superconcept <*superconceptName*> features

Table 5: Examples of argumentation templates

4.7 Insert Results in the O_c

The O_c is updated in two ways: whenever consensual elements are found in the O_i (Update O_c with (C)), or according to the results obtained in the negotiation process of divergences in the taxonomic position and/or in OntoClean metaproperties (Update O_c with TX_Results, OC_Results).

At the end of the negotiation process, the O_c will be the result of the merging among the O_i. O_n, representing the O_i evolution to be used by all participants until a new merging process occurs again.

As a result, O_c = merging of (O_i, .., O_n), while at the end of the process a new interaction assigns $O_i \leftarrow O_c$, and O_i becomes the start point of new updates. Each user thus keeps on modifying his/her O_i separately, which in its turn goes through successive new merging processes and guarantees that the conceptualization is shared by all participants.

5 Experiments and Evaluations

In order to evaluate the CAMIO method, two experiments of collaborative ontology development were carried out. The first experiment was conducted as to evaluate the proposed templates. The second one evaluated the effectiveness of the proposed method.

5.1 Evaluation Experiment of the Templates

Templates were evaluated in order to attest whether they indeed facilitated the understanding of the philosophical principles of identity, unity, essence, and dependence that correspond to the framework required for the assignment of OntoClean metaproperties in order to disguise the methodology complexity.

Only argumentation templates were evaluated as they are the core of the negotiation process and represent the majority of the templates in the method. In their turn, the other templates are intrinsically linked to the argumentation templates. If all templates of the CAMIO were tested, the process would become too repetitive for the participants, and thus would impair the evaluation goal.

Participants of this experiment are students pursuing the graduate degree - in Computer Science who had no experience with ontologies. A total of 27 students took part in the experiment, being 18 of them being in their second year with no previous knowledge of conceptual modeling and 9 on their fourth year with intermediate knowledge. Participants were divided into 9 groups of 3 members each.

The evaluation of the argumentation templates was conducted in two ways. Firstly, a free subjective evaluation on usability, training sufficiency, understanding of the chosen domain, general comments and suggestions was conducted. A free text questionnaire was used to carry out this evaluation.

Secondly, values were assigned so as to provide the understanding of each instantiated argumentation template. That was done by using a Likert scale, in which values vary from -2 (indicating no understanding) to +2 (indicating full understanding).

Each group dealt with the same group of individual ontologies $\{O_1, O_2, O_3\}$, given $O_1 \neq O_2 \neq O_3$ so that a consensual ontology O_c would be conceived. Versions of the O_i used were adapted from the [Guarino and Welty 04] ontologies. The individual ontologies O_i are composed of 24 concepts, of which 11 had divergences of OntoClean metaproperties and 2 divergences in taxonomic position.

Each group received a set of paper-based documents: a brief introduction on ontologies and OntoClean; the ontology (diagram); an overview of the ontology and its elements. Additionally, for each divergence in the O_i: a set of forms containing an issue to be discussed; the argument templates for solving the issue; a Likert scale for each argument in order to evaluate the template understanding.

Aiming to ensure that the participants would understand the intended meaning of the O_c elements, a debate was carried out as to discuss the O_c objective, its scope, and the meaning of the elements represented in the domain. Furthermore, a basic training was conducted as introduction to ontology development and the method used.

After the introductory training and with the documents on hand, each group gathered together and negotiated the issues for approximately 4 hours. Participants took notes of the arguments used to reach a conclusion as well as the voting results.

5.2 Results of the Pilot Experiment

With regard to the free evaluation of the CAMIO, about 70% of the participants referred to the method as positive, reporting its easy understanding and usability, the support provided by the templates in the decision-making process, and pointing out the increasing understanding of the method as the issues were addressed.

In the second evaluation, the understanding of each instantiated argumentation template was measured by using a Likert scale. The results obtained proved he understanding of the argumentation templates to be satisfactory, once most participants reached a nearly full understanding by choosing level 1 or 2 in the Likert scale. The results in [Tab.6] show that 79% of the participants reported the understanding of templates was nearly complete (participants that chosen options +1 and +2).

	Participants Evaluation				
Understanding level of the idea templatess	-2	-1	0	+1	+2
Results achieved	6%	7%	7%	15%	64%

Table 6: Understanding of the idea templates

In addition, the need for increasing the number of argumentation templates was detected, bearing in mind that some aspects of the philosophical principles considered in the templates are better adapted to the domain-dependent templates. For example, templates that are well adapted to living beings are not equally good for housewares. In this way, the second experiment employed an enlarged group of argument templates.

Furthermore, it was possible to verify that the metaproperty templates of identity and dependence scored more favorable evaluations, resulting in a larger number of hits in the assignment of such metaproperties.

5.3 Second Experiment

The main objective of this experiment was to evaluate the effectiveness of the CAMIO method regarding the reduction of the conceptual gap, i.e., check if the negotiation process based on justifications provided by the OntoClean methodology would produce ontologies (specified model) that approximate more to the conceptualization (intended model).

Participants of this experiment are students pursuing the graduate degree in Computer Science who had no experience with ontologies. A total of 33 students took part in the experiment, being 12 of them being in their second year with no previous knowledge of conceptual modeling, 12 in their third year with basic knowledge of conceptual modeling, and 9 in their fourth year with intermediate knowledge of conceptual modeling. Participants were divided into 11 groups of 3 members each.

Each member of a group made use of the CollArg prototype (to be presented in Section 5.4) to perform the merging of the O_i ontologies so as to conceive a consensual ontology O_c for the group. For each participant, an ontology of a set of individual ontologies $\{O_1, O_2, O_3\}$ was assigned, given $O_1 \neq O_2 \neq O_3$. Versions of the O_i used were adapted from the genealogy ontology of [Guizzardi 05].

The individual ontologies O_i are composed of 15 concepts with 60 OntoClean metaproperties. 15 issues were treated on divergences in OntoClean metaproperties and 9 divergences in taxonomic position.

In addition, the following material was made available on CollArg: an introduction to ontologies and OntoClean, a class diagram containing the individual ontology of each participant, a generic description of the ontology and its elements.

Aiming to ensure that the participants would understand the intended meaning of the O_c elements, a debate was carried out as to discuss the O_c objective, its scope, and the meaning of the elements represented in the domain. Also, a basic training was conducted as introduction to ontology development and the method used.

After the introductory training, all participants gathered together and each of them made use of the web-based CollArg prototype for merging the O_i and producing an O_c per group. Any relevant remark considered by the participants was separately reported. The experiment duration was of approximately 4 hours.

The method effectiveness evaluation was determined through the Precision and Recall values [Gangemi et al. 05] of the O_c conceived by the groups, compared to a golden standard ontology O_g that corresponds to the genealogy ontology of [Guizzardi 05]. Precision represents the ontology precision, evaluating the inexistence of unintended elements. In its turn, Recall represents the ontology coverage, evaluating the inclusion of all intended elements. Such values are calculated according to the standard values obtained from the comparison between O_c and O_g, :

- True Positive (TP): number of elements in the correct taxonomic position, and with correct attributions of OntoClean metaproperties in O_c compared with the elements of O_g.
- False Positive (FP): number of elements present in O_c, but not in O_g.
- False Negative (FN): number of elements present in O_g, but not in O_c.

[Fig. 6] presents the formulae for calculating Precision [Fig. 6 (A)] and Recall [Fig. 6 (B)] values, respectively.

$$Precision = \frac{TP}{TP + FP}$$

(A)

$$Recall = \frac{TP}{TP + FN}$$

(B)

Figure 6: Precision (A) and Recall (B) formulae

5.4 Prototype System Architecture and Implementation

In order to support the CAMIO method execution, an open-source prototype called CollArg was developed. The CollArg implements some features, such as:

- Execution in shared environment.
- Negotiation supporting mechanisms for solving divergences and subsumption constraints.
- Voting mechanisms for making decisions.
- Tracking of the results achieved: history of the divergences discussed, argumentations proposed, and results achieved.

The CollArg complies with the following specification: J2EE development, Glassfish application server, and web-based access interface (browser) implemented with JSF.

Negotiations are conducted through a conceptual-visual diagram [Fig. 7] that represents the consensual part of the O_c, while the divergences found among the O_i are negotiated as in the CAMIO proposal. Displays of this diagram are in accordance with the visual notation proposed by the ODM[10] (Ontology Definition Metamodel).

5.5 Results of the Second Experiment

The evaluation of the second experiment brought out favorable results regarding the precision and recall values of the O_c. [Gangemi et al. 05] consider good ontologies those that have high precision and maximum coverage.

[10] http://www.omg.org/spec/ODM/

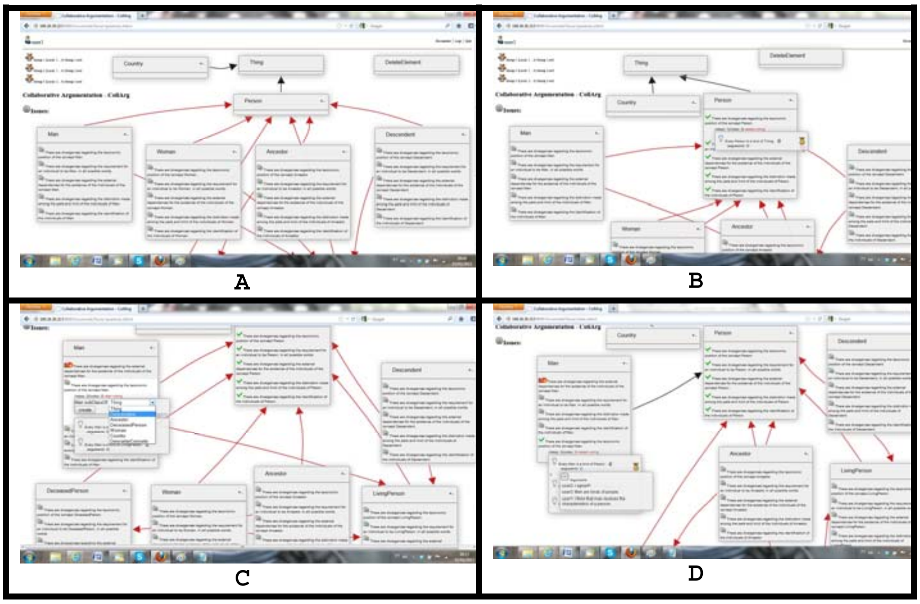

Figure 7: Examples of CollArg execution: (A) Concepts with divergences to be discussed (red arrows), (B) Winner idea for the taxonomic position of Person, (C) Proposition of a new idea for the taxonomic position of Person, (D)Arguments about the winner idea of Person.

The analyses of the results achieved [Tab. 7] shows that the coverage (Recall) reached an average of 0.75 and precision (Precision) reached 0.69. As coverage deals with the inclusion of the intended elements in the O_c, it is possible to analogically assert that in this experiment the O_c includes 75% of the intended model elements.

	4th year	3th year	2th year	Average	Standard Deviation
Precision	0.69	0.69	0.69	0.69	0.08
Recall	0.68	0.77	0.80	0.75	0.10

Table 7: Results of the Precision and Recall values in the second experiment

6 Related work

The CAMIO related work can be divided into two parts. The first part deals with approaches that use some form of argumentation for resolving differences found in collaborative ontology development. The second part deals with the application of the methodology OntoClean aiming to reduce the gap between the intended model and specified model, as well as to validate the ontology development.

With respect to the first part there are some collaborative approaches that make use of argumentation to support the negotiation process for solving divergences found in different conceptualizations. In [Aschoff et al. 04], the treatment of divergences is controlled by a moderator (with experience in Ontology Engineering) who is responsible for conducting and supporting argumentation among the participants.

In DOGMA-MESS [Leenheer and Debruyne 08] all members argue as to criticize and stand for their positions on the divergences until they reach a consensus.

Other approaches make use of methods for specifying and formalizing the argument types to be exchanged among the participants. In [Holsapple and Joshi 02] argumentation is founded on the Delphi Technique. In [Karapiperis and Apostolou 06] the Nominal Group Technique is used. DILIGENT [Tempich et al. 05], VIMethCOE [Jiménez Ruiz and Berlanga 06] and HCOME [Kotis and Vouros 06] strongly focus on the exchange of arguments structured by the IBIS. [Castro et al. 06] use the argumentative structure of DILIGENT [Tempich et al. 05] and include conceptual maps to support the participants' positions. In NEON Project [Suárez-Figueroa et al. 08] the arguments exchanged are also based in DILIGENT [Tempich et al. 05] and the Potts and Bruns model [Potts and Bruns 88] and are used to accelerate the convergence towards a solution.

These approaches usually indicate what are the problematic parts of ontologies, showing the errors that come from structural or logical consistency of the ontology [Haase and Stojanovic 08], however, do not provide any support for users to resolve these divergences.

The argumentation model used is either formal or semi-formal, that is to say they determine which types of arguments must be used in the argumentation[11] as a way to organize them. The content of the arguments, however, is free and based on the tacit knowledge of the participants or on informal examples.

This is the main difference in comparison to the CAMIO method, which provides justified arguments, based on the philosophical principles of OntoClean methodology grounded on the notions of essence, identity, unity, and dependence. These notions provide support for users in decision making, because it is possible to demonstrate the consequences of each modeling choice. This helps the users understand the assumptions made and make the meaning assigned to the elements of a domain partially explicit.

In the second part there are works that help users assign the mentioned OntoClean metaproperties. The OntoClean authors [Guarino and Welty 00c], developed a knowledge-based question/answer system that applies the methodology as a way to help clarify the modeling presumptions and produce well-founded taxonomies. Nevertheless, the system demands previous knowledge of the philosophical notions of identity, unity, essence, and dependence. Also, the authors themselves point out that the main impediment for its application consists in understanding when and under which conditions the identity and unity properties are used in a domain.

AEON [Völker et al. 08] is a tool used to automate the assignment of OntoClean metaproperties though searching usage patterns on the web, resulting in favorable or unfavorable evidences to the application or not of a metaproperty. Also, it validates the subsumption hierarchy of the labeled ontology.

[11] Argument types such as: issue, idea, justification, evaluation, example, challenge, counter-example, alternative, position, among others.

[Benevides and Guizzardi 09] propose a graphical editor to support the creation of conceptual models and domain ontologies in a modeling language called OntoUML. In this language, users work with a set of modeling standards for the application of model formation rules, reducing solution gaps that characterize the primitive modeling choices, and consequently, reducing the complexity of the model created. OntoUML is founded on the Universal Foundation Ontology (UFO), which in its turn is inspired in the Ontoclean.

Then, [Benevides et al. 10] developed an approach for evaluating the conceptual models defined in the OntoUML by simulating the structures of temporal worlds meant to reveal whether the specified model violates the intended model. Snapshots of this world structures confront modelers with states of affairs taken as acceptable by the model. In this way, modelers can detect unwanted states of affairs and make the appropriate decisions in order to adequate the model.

Although such approaches seek to make the OntoClean application transparent and facilitate its use, none of them refers to the collaborative ontology development or to its use in the negotiation/argumentation process. In the CAMIO, suggestions are made during or after the conceptual model construction as to improve the conceptual modeling itself, and thus reduce the cognitive load of the participants and try to express the conceptualization intention of the participants more precisely.

With the use of templates exemplifying the meaning of the OntoClean metaproperties in natural language, the CAMIO looks for a transparent application of the OntoClean methodology, hiding the difficulties encountered in choosing the metaproperties.

7 Conclusions

The main difference between the work proposed in this paper and current collaborative ontology development approaches resides in the formalization of the argumentation process as to offer justifications able to uphold the modeling decisions made by the modeler, facilitating and promoting a consensus. Such formalization is obtained through the application of the OntoClean methodology.

The OntoClean methodology was chosen to enable the proposed method because it is a unique approach towards the formal evaluation of ontologies (to the best of our knowledge) that attempts to explain the intentional content (through the use of meta-properties) in the definition of the concepts, besides takes into account the intension of this concepts when checking the taxonomic structure of the ontology.

Unlike OntoClean, other methodologies available to validate taxonomies, deal with structural consistency (with relation to the constructs that are allowed to compose the elements of an ontology) and logical consistency (checks if the ontology contains contradictory information) of the ontologies.

OntoClean methodology focuses on the validation of single subsumption relationship based on the intended meaning of their arguments in terms of the meta-properties defined, as opposed to focusing on structural similarities between property descriptions as other methodologies do.

Thus our motivation is to provide support for argumentation based on OntoClean in order to users make explicit part of their conceptual models (mental models). So, as a result of our work, we search for reduce the gap between the intended model and the specified model, obtaining a representation that is more adapted to the conceptualization intention and producing more correct ontologies in a collaborative way.

Another important point is that this work supports the collaborative ontology development in the specification and conceptualization stages, specifically. Then, since the CAMIO conducts an evaluation process in the conceptual modeling, it prevents modeling problems from propagating in subsequent tasks of ontologies' development lifecycle. By proposing the correction from a modeling perspective, seeks to guarantee the ontology validity regarding its formality (ontological rules), and encouraging the development of clean ontologies

The search for a transparent application of the OntoClean (through the use of the templates) aims at facilitating its use and reducing the cognitive load required for the application of this methodology, considered difficult for inexperienced users.

The evaluation of the first experiments conducted show results that indicate a transparent application of the OntoClean by the CAMIO. It was considered that most participants were inexperienced in conceptual modeling and that the other were at a maximum intermediate level, adding the fact that the participants had no knowledge of ontologies, and that in the two experiments more than 70% of the participants reported a clear understanding of the templates, once such understanding was also attested by the correct assignment of OntoClean metaproperties to the concepts of the collaborative ontologies.

With regard to the CAMIO effectiveness, the precision of the O_c developed in the second experiment reached 69% while coverage reached 75%. Considering that participants were inexperienced in ontology, this result indicates that the CAMIO can help the specification of ontologies that better approximate to their conceptualization.

8 Future Work

One of the difficulties in this work refers to the evaluation of the CAMIO, in respect to the use of some metrics adapted to measure the approximation of the models, as the ones presented in Section 6, or variations of those metrics. Further studies in the Psychology field are required in order to seek new evaluation methods for measuring such approximation. As an example, the work developed by [Evermann and Fang 10] makes use of conceptual hierarchy structures that reproduce human cognitive structures.

Also, new treatment methods of the framework used to assign the OntoClean metaproperties are prospected, e.g. through the design of scenarios used to support users when templates are not sufficient for an adequate understanding. In this case, users can call on the scenario as to better understand the template proposal. Another option would be the creation of a glossary in order to help them understand the meaning of the metaproperties.

Another key point refers to the conduction of new experiments in order to obtain a larger warehouse of test data and be able to conduct a better evaluation of the results achieved. In the next experiments, the collaborative ontology development is intended with two kinds of groups, called test and control. The test group will use the CAMIO and the control group will perform a free development, aiming to establish a comparative evaluation of the method.

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