Iterative, Incremental and Evolving EAF-based Negotiation Process

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Abstract Agents participating in a negotiation dialogue may use argumentation to support their position, hence achieving a better agreement. The Extensible Argumentation Framework (EAF) provides modularity and extensibility features that facilitates the adoption of argumentation by agents in MAS. In order to emphasize the EAF potential and applicability, this paper proposes an argument-based negotiation process grounded on the EAF adoption. Experiments demonstrate advantages of the proposal respecting conflict resolution and accuracy of the agreement.

1 Introduction

Internally agents may use argumentation for both (i) reasoning about what to believe (i.e. theoretical reasoning) and/or (ii) for deciding what to do (i.e. practical reasoning). Despite existing differences between both, from a standpoint of first-personal reflection, a set of considerations for and against a particular conclusion are drawn on both [1]. On the other hand, concerning the types of agents' dialogues (e.g. Deliberation, Negotiation, Persuasion, Inquiry, Information-seeking dialogues), while a clear distinction between each one exist, most of the agents' dialogue occurrences involve mixtures of dialogue types. Within this context, argumentation is seen as an activity where each participant tries to increase (or decrease) the acceptability of a given standpoint for the others participants by presenting arguments. In particular, agents participating in a negotiation dialogue may use argumentation to support their position and by that achieve a better agreement. Therefore, argumentation is foreseen as an adequate modeling formalism to reduce the gap between models governing the internal and external agent behavior. Grounded on that, this paper presents a novel, generic and domain independent argument-based negotiation process, in which are advocated the benefits of defining a common argumentation vocabulary shared by all agents participating in negotiation, which is internally extended by each of the agents to fit its own needs and knowledge. For that, the proposed argument-based negotiation process also requires that argumentation frameworks have modeling, modular and extensibility features. In that sense, the adoption of the Extensible Argumentation Framework (EAF) is suggested.

The rest of this paper is organized as follows: the next section describes the main structures and concepts of the EAF. Section 3 presents the proposed negotiation process based on the adoption of EAF in MAS [9]. Section 4 describes and summarizes the performed experiments in the domain of ontology alignment [2] applying the proposed negotiation process. Finally, section 5 draws conclusions and comments on future work.

2 Extensible Argumentation Framework

The Extensible Argumentation Framework (EAF) [10] is based and extends the Three-layer Argumentation Framework (TLAF) [3]. TLAF is a generic argumentation framework that, unlike others (e.g. AF [4], BAF [5], VAF [6]) comprehends three modeling layers. While the Meta-Model Layer and the Instance Layer roughly correspond to the (meta-) model layer and the instance layer of AF, BAF and VAF, the Model Layer does not have any correspondence in the surveyed abstract argumentation frameworks (illustrated in Fig. 1).

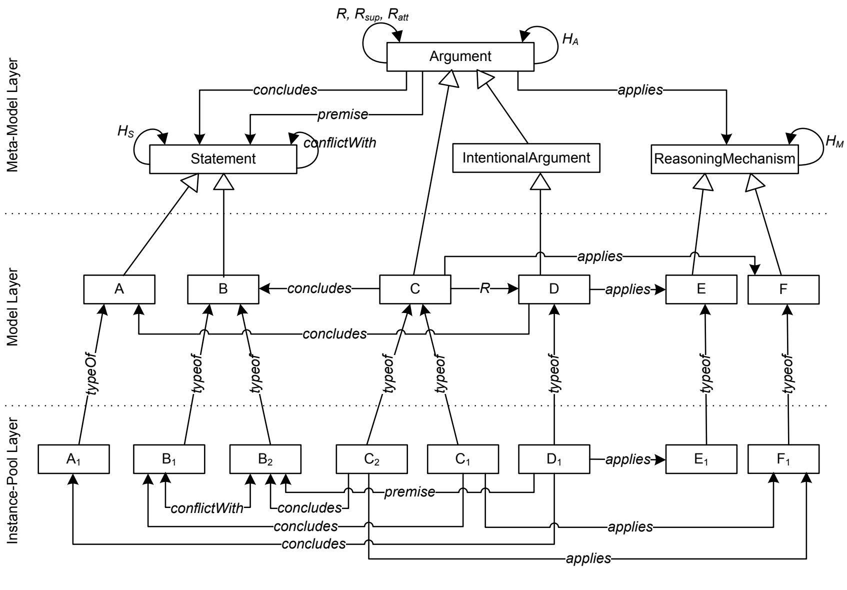

Fig. 1. The three modeling layers of TLAF/EAF

The Meta-model layer defines the core argumentation concepts and relations holding between them. TLAF adopts and extends the minimal definition presented by Walton in [7] where "an argument is a set of statements (propositions), made up of three parts, a conclusion, a set of premises, and an inference from premises to the conclusion". For that, the meta-model layer defines the notion of *Argument*, *Statement* and *Reasoning Mechanism*, and a set of relations between these concepts. An argument *applies* a reasoning mechanism (such as rules, methods, or processes) to *conclude* a conclusion-statement from a set of premise-statements. Intentional arguments are the arguments corresponding to intentions ([8, 9]).

The Model layer represents a conceptualization of arguments by defining the entities and their relations regarding both:

- the domain of application to be captured;
- the perception one (e.g. a community of agents or an individual agent) has about that domain.

The resulting model is further instantiated at the Instance-pool layer. The R relation is established between two argument types (e.g. $(C, D) \in R$) when C supports or attacks D. Through R it is also determined the types of statements that are admissible as premises of an argument.

Fig. 2 partially and graphically represents a simple argumentation model on the ontology matching domain. In this model, the intention to accept/reject a given correspondence between two ontological entities is captured by an argument of type *MatchArg* concluding a statement of type *MatchSt*. An argument of type *MatchArg* is affected (either supported or attacked) by arguments of type *TerminologicalArg* and *StructuralArg* concluding statements of type *TerminologicalSt* and *StructuralSt* respectively. All these arguments apply an *Heuristic* reasoning mechanism (not depicted in Fig. 2).

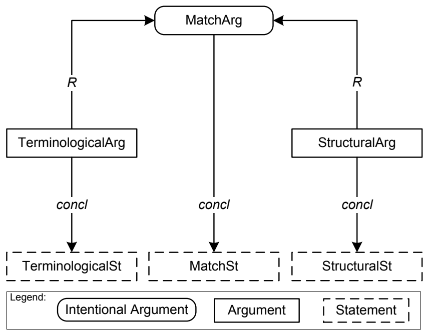

Fig. 2. Example of a TLAF model for the ontology matching domain

The Instance-Pool layer corresponds to the instantiation of a particular model layer for a given scenario. A statement-instance B_1 is said to be in conflict with another statement-instance B_2 when B_1 states something that implies or suggests that B_2 is not true. The statement conflict relation is asymmetric (in Fig. 1 B_2 conflicts with B_1 too). The support and attack relationships (R_{sup} and R_{att} respectively) between argument-instances are automatically inferred exploiting:

- the conceptual information (existing at the model layer), namely the R relations defined between argument-types;
- the extensional information (existing at the instance layer):
  - the premises and conclusions of the argument-instances;
  - the conflicts between statement-instances.

EAF extends TLAF by providing the constructs and respective semantics for supporting modularization and extensibility features to TLAF. In that sense, any EAF model is a TLAF model but not the inverse. In EAF model layer, arguments, statements and reasoning mechanisms can be structured through the H_A, H_S and H_M relations respectively. These are acyclic transitive relations established between similar entity types (e.g. arguments), in the sense that in some specific context entities of type e_1 are understood as entities of type e_2. While these relations are vaguely similar to the specialization relation (i.e. subclass/superclass between entities) it does not have the same semantics and it is constrained to 1-1 relationship (cf. [10]). An EAF model may reuse and further extend the argumentation conceptualizations of several existing EAF models. Inclusion of an EAF into another EAF is governed by a set of modularization constraints ensuring that no information of included EAF is lost. The extensibility feature of EAF is illustrated in the example depicted in Fig. 3 regarding the ontology matching domain.

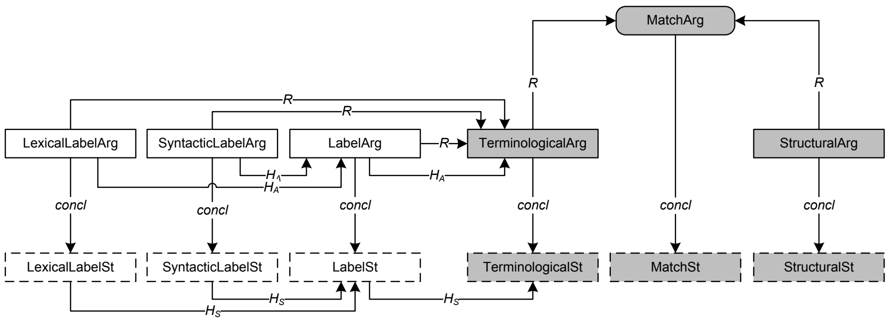

Fig. 3. Example of an EAF model with H_A and H_S relations

The EAF model depicted in this figure (called EAF_{OM_1}) extends the TLAF/EAF model previously depicted in Fig. 2 (called EAF_{OM}) such that the new arguments and statements are colored white while the arguments and statements of the extended model are colored gray. According to this example, the EAF semantics imply (for example) that any instance of *LexicalLabelArg* is understood and is translatable to an instance of *LabelArg*, which in turn is translatable into an instance of *TerminologicalArg*. In the argument exchange context, this feature is relevant considering that each agent internally adopting a distinct EAF model (e.g. EAF_{OM_1}) extended from a common/shared EAF model (e.g. EAF_{OM}) may translate arguments represented in their internal model to the shared model and, therefore, enabling the understanding of those arguments by the other agents.

3 The Argument-based Negotiation Process

This section proposes the argument-based negotiation process (ANP) based on the adoption of EAF by agents in MAS [9]. While other negotiation processes using EAF are admissible, we aim to provide an end-to-end negotiation process that emphasizes its potential and applicability.

3.1 Principles

Observations show that agreements through argumentation between humans follow an iterative and incremental process where arguments and counter-arguments are successively presented, enabling humans to identify the existing conflicts and further present more arguments and counter-arguments to (tentatively) resolve such conflicts.

Concerning the arguments formulation, humans usually exploit a huge diversity of information sources which may provide information that is more or less reliable, (in)complete, (in)coherent, (in)consistent and so on. Thus, each human usually selects and exploits information provided by the sources that are considered more reliable and trustable for the problem in hands.

Concerning the arguments understanding and reasoning, each human has a unique (i.e. its own) perception and rationality over the domain of the problem in hands. Therefore, arguments are seen, interpreted and evaluated in light of that individual perception. This fact enables humans to extract from the same set of arguments several distinct and contradictory conclusions.

Typically, the argumentation process ends either (i) when no more conflicts exist or (ii) when no more arguments are presented by any of the participants. In the former case, the argumentation always ends successfully since no conflicts exist anymore. In the latter case, the argumentation may end successfully or unsuccessfully depending on the degree of importance that each one gives to the remaining conflicts when compared to the agreement in hand. Thus, if the parties agree that the agreement in hand is better than no agreement at all then the argumentation ends successfully, otherwise it ends unsuccessfully.

At least but not less important, with respect to human beings' natural ability to evolve their knowledge and perception of the world and particularly about the domain under which they are arguing. A classical situation occurs when a human faces an argument put forward by another human and (s)he does not know its meaning or how that argument relates and affects the others known arguments. In such cases, that human may require a conceptual description of that kind of argument in order to figure out the missing knowledge and therefore acquire it. The resulting knowledge acquisition contributes to the evolution of its perception of the domain under discussion.

3.2 Overview

Within the proposed ANP the negotiation entities (e.g. persons, organizations) are represented by agents. Yet, as with any other negotiation process, the proposed argument-based negotiation process happens, at least, between two agents. Furthermore, it is assumed that the negotiation occurs in the scope of a given community of agents. When joining a community, the agent is (implicitly or explicitly) accepting a set of rules by which all agents interactions are governed. One of the main rules is related to the key notion/concept of argumentation model, which in turn substantially constrains the characteristics of the argumentation process.

Definition 1 (Argumentation Model). An argumentation model (AM) is an artifact that captures (partially or totally) the perception and rationality that an agent has about a specific domain (e.g. ontology matching) regarding the argumentation process.

According to Definition 1, the argumentation model might conceptually define the vocabulary used to form arguments, the arguments' structure and even the way arguments affect (i.e. attack and support) each other. Hence, a model is a specification used for stating model commitments. In practice, a model commitment is an agreement to use a vocabulary in a way that is consistent (but not necessarily complete) with respect to the theory specified by the model [11]. Agents commit to models which are designed so that the domain knowledge can be shared among these agents.

The community of agents on which the negotiation process occurs is responsible for defining a public argumentation model.

Definition 2 (Public Argumentation Model). A public argumentation model is a shared argumentation model capturing the common understanding about argumentation over the domain problem being addressed (e.g. ontology matching) of a community of agents.

All agents of that community are able to understand the defined public argumentation model and reason on it. Further, each agent must be able to extend the public argumentation model so it better fits its own needs and knowledge. As a result, the agents freely specify their private argumentation model.

Definition 3 (Private Argumentation Model). A private argumentation model is an argumentation model capturing the understanding about argumentation over the domain problem being addressed (e.g. ontology matching) of a single agent.

While a public argumentation model represents a shared knowledge/perception between agents, a private argumentation model represents the individual perception/knowledge that an agent has.

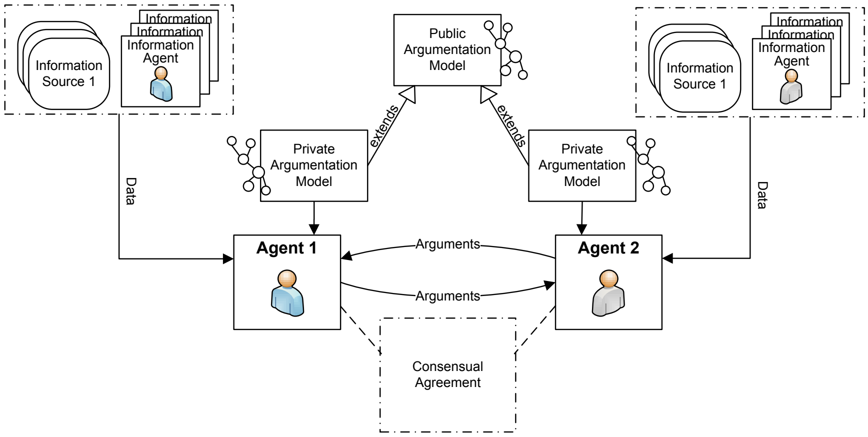

Fig. 4. Overview of the argument-based negotiation process

Because the agents adopt their own private argumentation model, each agent has the responsibility for searching, identifying and selecting the sources of information that can provide the most relevant and significant information needed to instantiate its private model. After the private model instantiation each agent has a set of arguments that need to be evaluated in order to extract the agent consistent position, i.e. a *preferred extension*. A *preferred extension* includes two kinds of argument: intentional arguments and non-intentional arguments. The former ones define the intentions of the agent with respect to the agreement, while the latter ones represent the set of reasons supporting the intentions. By exchanging the intentional arguments of their *preferred extensions*, agents are able to identify the existing conflicts and argue with non-intentional arguments.

It is worth noticing that the EAF model layer together with the extensibility and modularization features satisfies the above definitions of public/private argumentation model. Therefore, from now the ANP description adopts EAF.

3.3 Phases of the Negotiation Process

Considering the premises described in previous section, a general argument-based negotiation process was devised. The phases of each agent's negotiation process, the flow of data and the interactions with other agents are depicted in Fig. 5.

3.3.1 Setup

The Setup phase defines the context of the negotiation. At the end of this phase all participating agents know and agree with this context. For that, the participating agents will engage in a set of interactions aiming for:

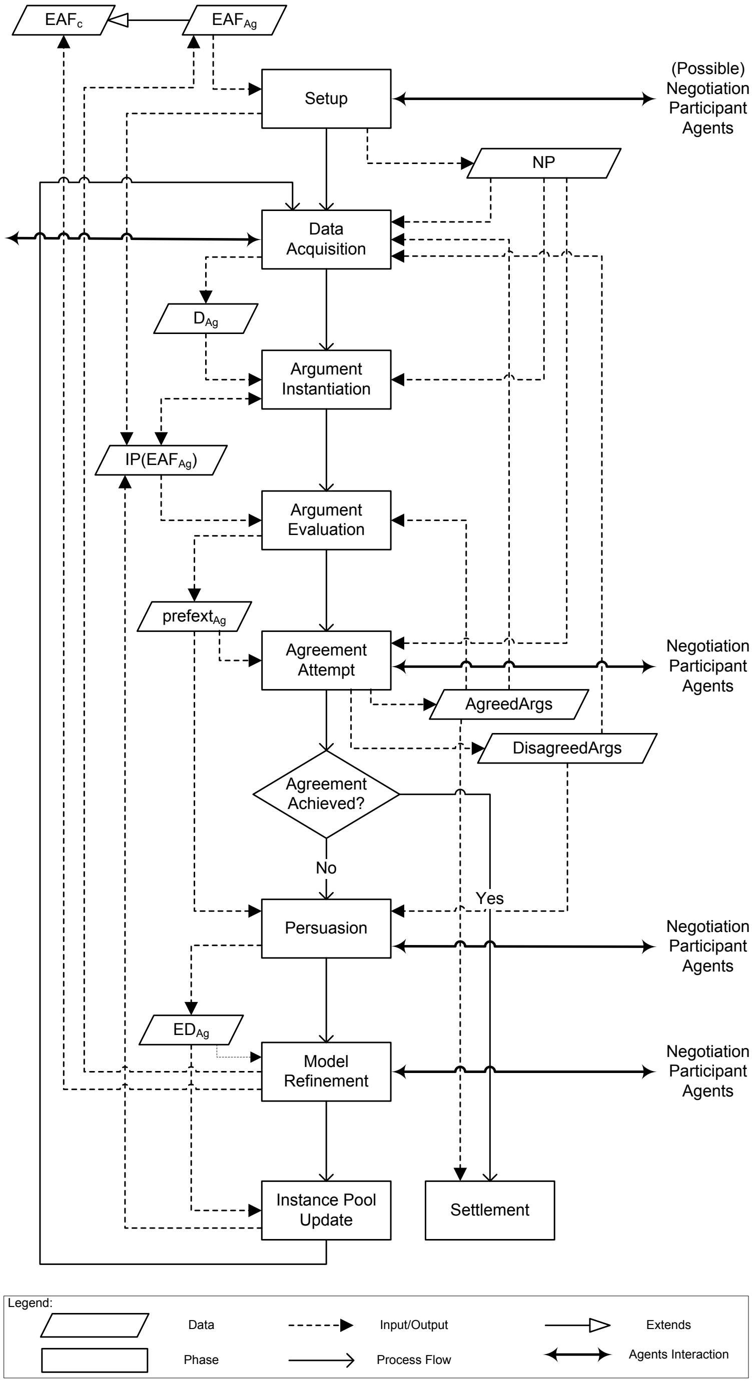

Fig. 5. The proposed argument-based negotiation process

- the identification of the (possible) negotiation participants;
- the identification of the community's minimal common understanding, i.e. the public argumentation model (EAF_C) between all participants;
- the definition of the required negotiation parameters/constraints such as deadline for achieving an agreement;
- the specification of the negotiation method to compute a possible agreement between participants;
- the establishment of special rights for some of the participants;
- the sharing of the data/information that is required by the agents in order to participate in the negotiation (e.g. the ontology used by each agent).

These interactions will result in the definition of a set of constraints called the negotiation parameters (NP). Complementary to the negotiation parameters, each participant creates an instance-pool of its own argumentation model ($IP(EAF_{Ag})$) that will capture the argumentation data. In contrast to the other phases, this phase occurs only once.

3.3.2 Data Acquisition

During the Data Acquisition phase the agent collects the data/information that constitutes the grounds to generate the arguments (called D_{Ag}). For that, the agents may interact with other agents not directly participating in the negotiation process. It might be the case of specialized agents on the subject under discussion. The tentative agreements generated in the upcoming phases may be used as input information to the data-collecting mechanisms too.

3.3 .3 Argument Instantiation

The goal of the Argument Instantiation phase is the instantiation of the agent's instance-pool of the argumentation model ($IP(EAF_{Ag})$) based on the collected data (D_{Ag}). For that, the agent makes use of one or more data transformation processes over the collected data, generating a set of arguments structured according to the adopted argumentation model. In order to properly (re)classify the argument instances is foreseen the need of an instances (re)classification process. It is also envisaged that this (re)classification process might be further reused in the Instance-Pool Update phase. However that is not mandatory. This process is extensively addressed in [3] and [12].

3.3.4 Argument Evaluation

In the Argument Evaluation phase, each agent extracts a *preferred extension*, i.e. a consistent position within $IP(EAF_{Ag})$ which is defensible against any attack and cannot be further extended without introducing a conflict. According to the agent's $IP(AM_{Ag})$ one or more possible *preferred extensions* may be extracted.

If the argument evaluation process extracted more than one *preferred extension* then it is necessary to select one. The selection criterion has a special relevance during the negotiation process because it directly defines the agent's intentions and the reasons behind those intentions. Given that, instead of a simple criterion, a more elaborate selection criterion may be taken into consideration. For example, instead of the "selection of the *preferred extension* that is maximal with respect to set inclusion", one may consider "the *preferred extension* that minimizes the changes in respect to the previous one.

This phase occurs iteratively depending on the acquisition of new data/information and especially on the exchange of arguments between the agents during the persuasion phase. Because any change made to $IP(EAF_{Ag})$ suggests that the agent's consistent position may change, a re-evaluation of the *preferred extension* is necessary.

3.3.5 Agreement Attempt

In the Agreement Attempt phase each participant makes an agreement proposal to the other agent(s) (called the candidate agreement). If accepted it will be settled by all participants.

This phase consists of two steps. In the first step, each agent makes its agreement proposal by exchanging the intentional arguments of its *preferred extension* only (called the *intentional preferred extension*). As a result of all proposals, two sets of arguments are derived and shared by all agents:

- the set of arguments agreed/proposed by all agents ($AgreedArgs$) which represents a candidate agreement;
- the set of arguments which at least one agent disagrees ($DisagreedArgs$). For a negotiation between n agents where $iprefext_{Ag_i}$ is the *intentional preferred extension* of agent i, these sets can be computed differently depending on the agents and according to the setup phase. One of the simplest agreement evaluation forms is based on their intersection:

$$AgreedArgs = \bigcap_{i=1}^{n} iprefext_{Ag_i}$$

$$DisagreedArgs = \left(\bigcup_{i=1}^{n} iprefext_{Ag_i}\right) - AgreedArgs$$

In the second step, each participant evaluates its level of satisfaction of the current candidate agreement. For that the agent considers the defined negotiation parameters/constraints (NP) and the content of the $DisagreedArgs$ set. According to the level of satisfaction, the participants must decide to whether to:

- continue the negotiation, and therefore proceed to the persuasion phase; or
- conclude the negotiation, which is either:
  - successful if all agents accept the candidate agreement ($AgreedArgs$). In such case the process proceeds to the settlement phase; or
  - unsuccessful if the candidate agreement is not accepted by all agents and they do not continue the negotiation. In this case no agreement is achieved.

3.3.6 Persuasion

In the previous phase a set of conflicts/disagreements have been identified (in the form of intentional arguments) that were not accepted by at least one participant ($DisagreedArgs$). In this phase each agent tries to persuade the others to accept its intentions. For that, each agent exchange arguments supporting its *preferred extension* and arguments attacking the other agents' *preferred extension(s)*.

Each agent first selects from its *preferred extension* a (sub-) set of arguments supporting or attacking the arguments existing in $DisagreedArgs$. The selected arguments will be exchanged with the opponent agents to persuade them. There are two forms of exchanging the arguments:

1. The arguments are exchanged according to the EAF_c and not according to EAF_{Ag}, so the other agents can understand them. Due to the H_A, H_S and H_M relations, the transformation of the instances respecting the agent's EAF to the community EAF is straightforward. Thus, arguments represented according to the agent's argumentation model EAF_{Ag} that cannot be expressed in terms of EAF_C are not exchanged;
2. The arguments are exchanged according to the EAF_{Ag} along with the EAF_{Ag} parts that allow the other agent to transform the arguments to EAF_c. This arguments exchange method requires that agents have the ability to teach and to learn from other agents such that agents may evolve over time their perception/knowledge.

Independently of the exchanged method (decided in the Setup phase), at the end of this phase, each agent has collected a new set of arguments presented by the other negotiating agents (ED_{Ag}). These arguments will be exploited in the Instance-Pool Update phase.

3.3.7 Model Refinement

This phase concerns the refinement of the community's argumentation model (EAF_C) according to the exchanged arguments and the agents' argumentation models. If the exchange of arguments does not include exchanging parts of the agent's private argumentation model, this phase is more difficult and therefore may be skipped.

While it is not the aim of this description to present an evolution process of the argumentation model, nor the agents' reasoning process leading to such evolution, it is important to emphasize the need to evolve (over time) the community's argumentation model according to the agents' needs.

3.3.8 Instance-Pool Update

In this phase, the agent analyzes, processes and possibly reclassifies the ED_{Ag} arguments in light of its EAF_{Ag}. The ED_{Ag} arguments that are understood (in the light of EAF_{Ag} or EAF_C) and do not exist in $IP(EAF_{Ag})$ are added while duplicated arguments are discarded. The added arguments are taken into consideration by the agent in the next round of proposals. The negotiation process proceeds to the Data Acquisition phase.

3.3.9 Settlement

The goal of the settlement phase is to transform the candidate agreement into a definitive agreement according to the settlement parameters of NP. In that respect, this phase is seen as an initiator of a set of transactions that occur after the agreed terms are known in order to fulfill the terms.

The set of transactions varies according to the domain of application and the negotiation object (e.g. goods or services) as well as the participating agent. On the other hand, in an e-commerce scenario, fulfilling an agreement for selling physical goods may imply forwarding the agreement to the logistic and financial services.

4 Experiments

Since the proposed negotiation approach is domain independent, one needs a domain of application to evaluate the proposed argument-based negotiation approach. We choose to resolve conflicts arising between agents when they are reconciling the vocabulary used in their ontologies. The result of the vocabulary reconciliation is a set of correspondences (an alignment) between entities of the agents' ontologies. Such conflicts arise because each agent may have its own perspective about what are the best correspondences. The experiments aim to measure the (i) conflicts resolved and (ii) the improvement produced in the accuracy of the agreed alignment, when compared to each agent's initial alignment.

4.1 Setup

We adopted an empirical approach using:

- a publicly available set of pairs of ontologies exploited in several ontology alignment initiatives (Table 1);

Table 1. Set of pair of ontologies used in the experiments

Source Ontology	Target Ontology	Nr. Correspondences
animalsA[1]	animalsB[1]	24
russia1[1]	russia2[1]	65
russiaA[1]	russiaB[1]	160
russiaC[1]	russiaD[1]	135
sportEvent[1]	sportSoccer[1]	149
Vehicles1[1]	Vehicles2[1]	4
onto101[2]	onto103[2]	97
onto101[2]	onto104[2]	97
onto101[2]	onto204[2]	97
onto101[2]	onto205[2]	97
onto101[2]	onto221[2]	97
onto101[2]	onto222[2]	93
onto101[2]	onto223[2]	97
onto101[2]	onto301[2]	45
onto101[2]	onto302[2]	37
onto101[2]	onto303[2]	32
onto101[2]	onto304[2]	56

- for each pair of ontologies a widely accepted reference alignment that will be used to evaluate the negotiation results. For the sake of brevity and simplicity, the results are presented considering the negotiation of all individual alignments as just one huge alignment with 1402 correspondences;
- three agents (A, B and C) with different configurations, including:
  - different EAF models (EAF_{Ag_A}, EAF_{Ag_B} and EAF_{Ag_C}) extended from a common one. These EAF models are illustrated in Fig. 6, Fig. 7 and Fig. 8 respectively, where grayed arguments refer to the community's common argumentation model;
  - distinct set of matching algorithms (or matchers) were used to collect ontological correspondences which are further used to generate argument-instances (Table 2, Table 3 and Table 4);

[1] Available at http://www.dei.isep.ipp.pt/~pmaio/goals/Ontologies/.

[2] Available at http://oaei.ontologymatching.org/2009/benchmarks/

– based on the H_A, H_S and H_M, the agents have the capability to reclassified internally the argument-instances as depicted in Table 5. Notice that this table reflects the agents' internal and private knowledge, thus an agent does not know the reclassification rules of the other agents.

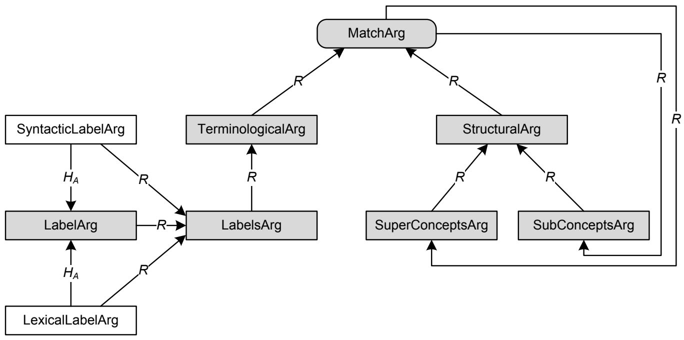

Fig. 6. The argumentation model internally adopted by Agent A

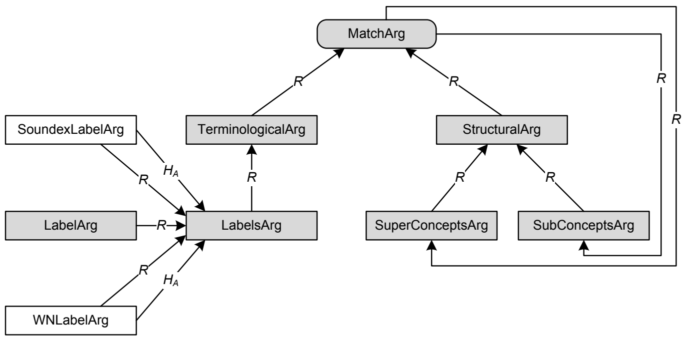

Fig. 7. The argumentation model internally adopted by Agent B

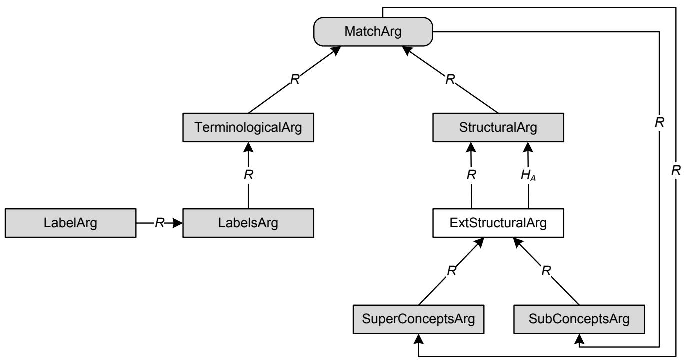

Fig. 8. The argumentation model internally adopted by Agent C

The adopted argument instantiation process is described in [12]. It relies on an interpretation function that allows transforming a correspondence $c = (e, e', r, n)$ provided by a matching algorithm (G) into a statement-instance $s = (G, c, pos)$ such that $pos \in \{+, -\}$ states if the matcher is in favor $(+)$ or against $(-)$ the correspondence c. The matcher position is determined based on the thresholds tr_+ and tr_- such that: if $n \geq tr_+$ then the matcher is in favor of c, otherwise if $n < tr_-$ then the matcher is against c. If the matcher is neither for nor against c the correspondence is ignored. The resulting statement-instance is further concluded by an argument-instance based on a set of inferred premise statement-instances. The interpretation functions adopted by agent A, B and C are represented in Table 2, Table 3 and Table 4 respectively.

Table 2. The interpretation function of Agent A

ID	**Matcher Description**	**Correspondence Content**	**Statement Type**	**Reasoning Mechanism**	tr_+	tr_-
G_{A1}	WNMatcher [13]	any	LexicalLabelSt	Heuristic	1.00	1.00
G_{A2}	String-distance [14]	any	SyntaticalLabelSt	Heuristic	0.75	0.75
G_{A3}	V-Doc [14]	any	LabelSt	Heuristic	0.70	0.70
G_{A4}	$MaxAgg(G_{A1}, G_{A2})$[3]	any	TerminologicalSt	Heuristic	0.50	0.50
G_{A5}	GMO [14]	any	SuperConceptsSt	Heuristic	0.50	0.50
G_{A6}	Falcon-AO [14]	any	MatchSt	Heuristic	0.70	0.70

Table 3. The interpretation function of Agent B

ID	**Matcher Description**	**Correspondence Content**	**Statement Type**	**Reasoning Mechanism**	tr_+	tr_-
G_{B1}	Soundex [15][4]	any	SoundexLabelSt	Heuristic	0.75	0.75
G_{B2}	WNPlusMatcher [13]	any	WNLabelSt	Heuristic	1.00	1.00
G_{B3}	BiGram[5]	any	LabelSt	Heuristic	0.75	0.75
G_{B4}	$OWAAgg(G_{B1}, G_{B2}, G_{B3})$[6]	any	TerminologicalSt	Heuristic	0.60	0.60
G_{B5}	StructureMatcher [13]	any	SuperConceptsSt	Heuristic	0.70	0.70
G_{B6}	Sub-hierarchy [18]	any	SubConceptsSt	Heuristic	0.30	0.30
G_{B7}	$MaxAgg(G_{B2}, SMOA$ [19])	any	MatchSt	Heuristic	0.25	0.25

[3] Corresponds to the aggregation of the alignments generated by the input matching algorithms through the max function.

[4] Implemented in the SimMetrics project available at http://sourceforge.net/projects/simmetrics/.

[5] Implemented in the SimPack [16].

[6] Corresponds to the aggregation of the alignments generated by the input matching algorithms through the OWA operator [17].

Table 4. The interpretation function of Agent C

ID	Matcher Description	Correspondence Content	Statement Type	Reasoning Mechanism	tr_+	tr_-
G_{C1}	Levenshtein [20]	any	LabelSt	Heuristic	1.00	1.00
G_{C2}	WNPlusMatcher [13]	any	LabelSt	Heuristic	0.75	0.75
G_{C3}	$AvgAgg(G_{C1}, G_{C2}, SMOA)$[7]	any	TerminologicalSt	Heuristic	0.70	0.70
G_{C4}	Super-hierarchy [18]	any	SuperConceptsSt	Heuristic	0.70	0.70
G_{C5}	Sub-hierarchy [18]	any	SubConceptsSt	Heuristic	0.70	0.70
G_{C6}	$AvgAgg(G_{B5}, SMOA)$	any	StructuralSt	Heuristic	0.70	0.70
G_{C7}	$Op(MaxAgg(G_{C2}, SMOA, G_{B5})$[8]	any	MatchSt	Heuristic	0.25	0.25

Table 5. Reclassification of statement-instances based on its content

Agent	Statement-Content		EAF_A		EAF_B
	Type	Matcher	LexicalLabelSt	SyntaticLabelSt	WNLabelSt
A	LexicalLabelSt	G_{A1}	-	-	X
B	WNLabelSt	G_{B2}	X	-	-
B	SoundexLabelSt	G_{B3}	-	X	-
C	LabelSt	G_{C1}	X	-	X
C	LabelSt	G_{C2}	-	X	-

As an example, argument-instances sent by agent A whose conclusion is a statement-instance of type *LexicalLabelSt* that were generated based on a correspondence provided by G_{A1} are further reclassified by agent B to statement-instances of type *WNLabelSt* and, therefore, to argument-instances of type *WNLabelArg*.

4.2 Results

Table 6 summarizes and characterizes the automatic alignment of each agent before the negotiation process by presenting the (information retrieval) measures of Precision, Recall and F-Measure[9]. Correct correspondences are those that exist in the reference alignment.

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[7] Corresponds to the aggregation of the alignments generated by the input matching algorithms through the linear average function.

[8] Corresponds to the global optimization of the input alignment by the Hungarian method [21].

[9] F-Measure is the harmonic mean of Precision and Recall.

Table 6. Agents' alignment before the negotiation process

Agent	Correspondences		Accuracy (%)		
	Proposed	Correct	Precision	Recall	F-Measure
A	1358	1296	95.4	92.4	93.9
B	2025	1266	62.5	90.3	73.9
C	1290	1219	94.5	86.9	90.6

Table 7 summarizes and characterizes the agreed alignment between each possible pair of agents.

Table 7. Agreed Alignment between agents

Agents	Correspondences		Accuracy(%)		
	Proposed	Correct	Precision	Recall	F-Measure
A-B	1294	1243	96.1	88.7	92.2
A-C	1250	1214	97.1	86.6	91.6
B-C	1387	1234	89.0	88.0	88.5

Table 8 summarizes and characterizes the amount of conflicts addressed during the negotiation process and the quality of the occurred persuasion. For each pair of agents, the table shows:

- the amount of conflicts before the negotiation process starts and the amount of those conflicts that are about correspondences belonging to the reference alignment (R.A);
- the amount of conflicts that remain to be resolved at the end of the negotiation process and the amount of those conflicts that are about correspondences belonging to the reference alignment (R.A);
- the amount of resolved conflicts and the corresponding amount of those conflicts that were correctly and badly resolved regarding both the agreed alignment and the reference alignment;
- the rate of persuasion occurred between the agents (i.e. rate of resolved conflicts) and the quality of that persuasion.

Table 8. Conflicts addressed during the negotiation process

Agents	Conflicts							Persuasion (%)		
	Initial		Remain		Resolved					
	Total	R.A.	Total	R.A.	Total	Correct	Bad	Total	Good	Bad
A-B	813	78	308	67	505	487	18	62.1	96.4	3.6
A-C	200	119	130	90	70	47	23	35.0	67.1	32.9
B-C	779	75	223	39	556	459	97	71.7	82.6	17.4

4.3 Analysis and Discussion

Regarding the conflicts resolution, the examination of the results shows that the proposed negotiation process allows agents to resolve their conflicts. However, as it was expected the amount of resolved conflicts depends of the persuasiveness of the negotiating agents. In that sense, several levels of persuasiveness were observed (from 35% to 71.7%). Even though, the rate of good persuasion is always high since it varies between 67.1% and 96.4%. While these results may depend of several and distinct factors, one might conclude that they are independently of the amount of resolved conflicts.

Yet, comparing the initial amount of conflicts about correspondences belonging to the reference alignment and the amount of those conflicts that remains when the negotiation process ends, it is perceivable that it is very hard for an agent to successfully persuade its opponent to change position about a correct correspondence proposed by its opponent.

Comparing the alignment devised individually by the agents with the agreed alignment, one might say that agents profit with the argumentation process:

- agent A agreed two alignments which are, in terms of f-measure, at maximum 2.3% worse than the one devised by itself;
- agent B improved its alignment whose f-measure is around 74% to an agreed alignment whose f-measure is at least 88%, i.e. an increase of 14%;
- agent C agreed an alignment with agent B which is, in terms of f-measure, around 2% worse than the one devised by itself, but it has improved around 1% in the agreed alignment with agent A;

These f-measure variations happened at the same time that conflicts are resolved. Considering that, differences observed in the f-measure of the agreed alignments of agent A and C are negligible. On the other hand, the improvement achieved by agent B is very significant.

5 Conclusions

This paper describes conceptually a novel, generic and domain independent argument-based negotiation occurring between parts. Thus, it does not specify/defend/provide any implementation details, such as (i) the agents' communication language to adopt, (ii) the exchanging messages, their structure and protocol, (iii) the algorithms to be adopted in each task/phase and (iv) the data sources to be exploited. While all these dimensions are important, the abstraction proposed by the ANP allows:

- to identify the core notion of argumentation model and its influence on the other dimensions;

- to systematize and organize the phases of a negotiation based on arguments from the perspective of an agent and, therefore, the phases become task-oriented;
- to clearly identify the actors and their roles in the negotiation process and namely on which phases they act and interact;
- to identify the main blocks of data/information used as input and as output of the phases of the process;

In face of that, the proposed ANP also advocates:

- an iterative and incremental flow of the results between the phases of the negotiation process;
- four characteristics to any argumentation model: sharable, reusable, extensible and modular;
- the idea that the negotiation participants have distinct knowledge and perspectives about the domain application being argued/negotiated;
- that despite the negotiation participants have distinct knowledge and perspectives about the domain application, a part of that knowledge is shared to foster the exchanged argument understanding;

As a consequence, the process is sufficiently generic to be adopted in a wide range of domains.

This paper also suggested the adoption of the Extensible Argumentation Framework because, contrary to the abstract argumentation frameworks such as AF [4], BAF [5], VAF [6], it comprehends a modeling layer whose content is sharable and reusable through its modularity and extensibility features. By adopting the EAF, agents are able to share an external common argumentation model which is further extended internally by each agent to better fit its own needs and knowledge. Yet, the common argumentation model may continuously evolve along the time profiting from occurring negotiation interaction between agents.

The proposed negotiation process also promotes the use of argumentation as a common formalism either for (i) agents' internal reasoning and (ii) agents interactions (namely negotiation interactions).

Experiments in the ontology alignment field show that the adoption of the proposed ANP together with the adoption of the EAF leads to improvements in the quality of the agreed ontology alignment when compared with agents' individual ontology alignment while conflicts are resolved. High rates of good persuasion are achieved independently of the amount of resolved conflicts.

An interesting research direction concerns providing agents with the ability (i) to learn and improve their argumentation strategies based on their past experiences and (ii) to learn (and understand) new arguments used by other agents in order to apply in the Community's Model Refinement phase.

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References

1. Moran, R.: Authority and Estrangement: An Essay on Self-Knowledge. Princeton University Press (2001).
2. Euzenat, J., Shvaiko, P.: Ontology Matching. Springer, Heidelberg, Germany (2007).
3. Maio, P., Silva, N.: A Three-Layer Argumentation Framework. First Int. Workshop on the Theory and Applications of Formal Argumentation at IJCAI. Barcelona, Spain (2011).
4. Dung, P.M.: On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. Artificial Intelligence. 77, 321—358 (1995).
5. Cayrol, C., Lagasquie-Schiex, M.C.: On the Acceptability of Arguments in Bipolar Argumentation Frameworks. Symbolic and Quantitative Approaches to Reasoning with Uncertainty. pp. 378-389 (2005).
6. Bench-Capon, T.: Persuasion in Practical Argument Using Value-based Argumentation Frameworks. Journal of Logic and Computation. 13, 429—448 (2003).
7. Walton, D.: Argumentation Theory: A Very Short Introduction. in Argumentation in Artificial Intelligence. pp. 1-22 Springer US, Boston, MA (2009).
8. Bratman, M.E.: Intention, Plans, and Practical Reason. Center for the Study of Language and Information (1999).
9. Wooldridge, M.: An Introduction to MultiAgent Systems. John Wiley & Sons (2009).
10. Maio, P., Silva, N.: Tech. report: The Extensible Argumentation Framework. ISEP, Porto, Portugal (2011).
11. Gruber, T.R.: A translation approach to portable ontology specifications. Journal of Knowledge Acquisition. 5, 199—220 (1993).
12. Maio, P., Silva, N., Cardoso, J.: Generating Arguments for Ontology Matching. 10th Int Workshop on Web Semantics (WebS) at DEXA. Toulouse, France (2011).
13. Kalfoglou, Y., Hu, B., Shadbolt, N., Reynolds, D.: CROSI-Capturing Representing and Operationalising Semantic Integration, http://www.aktors.org/crosi/.
14. Jian, N., Hu, W., Cheng, G., Qu, Y.: Falcon-AO: Aligning Ontologies with Falcon. Proc. K-CAP Workshop on Integrating Ontologies. p. 87—93 , Banff (CA) (2005).
15. Russell, R.C.: US Patent 1261167 (A), (1918).
16. Bernstein, A., Kaufmann, E., Kiefer, C., Burki, C.: SimPack: A Generic Java Library for Similarity Measures in Ontologies. Tech. report, Univ..Zurich, Dpt. of Informatics. (2005).
17. Ji, Q., Haase, P., Qi, G.: Combination of Similarity measures in Ontology Matching using the OWA Operator. Proc. of the 12th Int. Conf. on Information Processing and Management of Uncertainty in Knowledge-Base Systems (IPMU'08). (2008).
18. Maio, P., Silva, N.: GOALS - A test-bed for ontology matching. 1st IC3K Int. Conf. on Knowledge Engineering and Ontology Development (KEOD), Funchal Portugal (2009).
19. Stoilos, G., Stamou, G., Kollias, S.: A string metric for ontology alignment. The Semantic Web–ISWC 2005. 624–637 (2005).
20. Levenshtein, V.: Binary codes capable of correcting deletions, insertions, and reversals. Doklady akademii nauk SSSR. 163, 845—848 (1965).
21. Munkres, J.: Algorithms for the Assignment and Transportation Problems. Journal of the Society for Industrial and Applied Mathematics. 5, 32-38 (1957).