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 its adoption 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.

Categories and Subject Descriptors
I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence – agents, *multi-agent systems, negotiation, argumentation.*

Keywords
Negotiation, Argumentation, Agents, MAS

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 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 generic negotiation process that exploits the expressivity, modularity and extensibility features of the Extensible Argumentation Framework (EAF) [2]. The core idea behind the EAF-based process is: while a common argumentation vocabulary is shared by all agents, internally each agent is able to extend that vocabulary to fit its own needs and knowledge.

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. Section 4 presents a brief summary of performed experiments in the domain of ontology alignment [3] applying the proposed negotiation process. Finally, section 5 draws conclusions and comments on future work.

2. The EAF

This section describes briefly and informally the main features of the Extensible Argumentation Framework (EAF). The EAF comprehends three modeling layers as depicted in Figure 1.

The Meta-model layer defines the core argumentation concepts and relations holding between them. EAF adopts and extends the minimal definition presented by Walton in [4] 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 ([5], [6]).

The Model layer defines the entities and their relations for a specific domain according to a community's perception. 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. Additionally, 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.

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 Figure 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 (i) the R relations defined at the model layer and (ii) the existing *premise* relations and the statements conflicts at this level.

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.

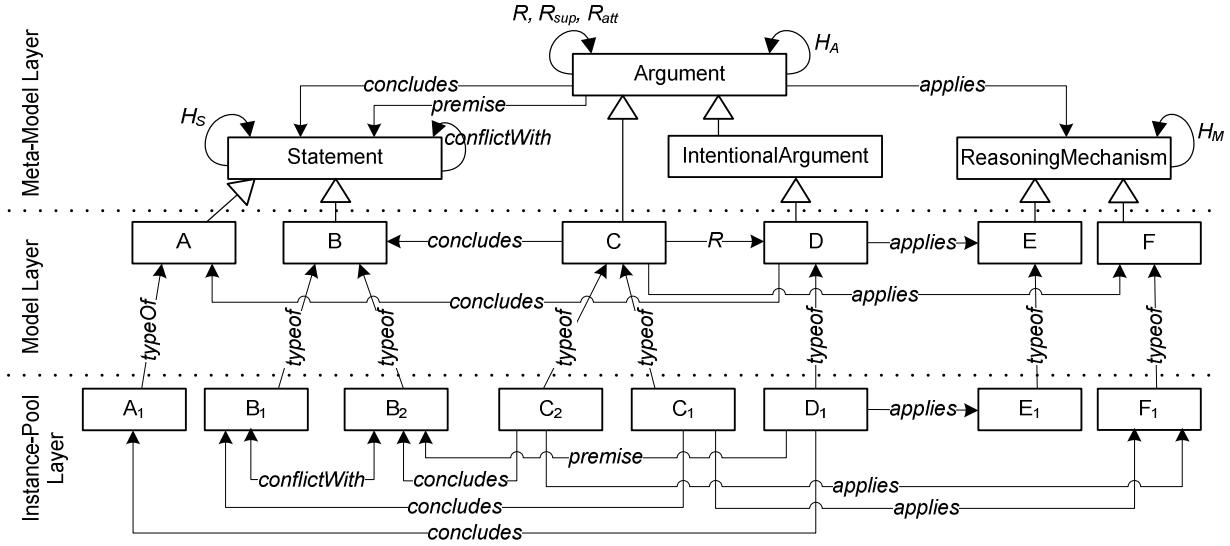

Figure 1. The three modeling layers of EAF

3. NEGOTIATION PROCESS

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

The proposed negotiation process relies on the following assumptions: (i) a negotiation process between two or more agents always occurs in the scope of a given community of agents, (ii) the agents' community is able to define an EAF model (i.e.EAF_c) representing the community minimal common understanding about the domain of discourse that all agents of that community are able to understand, and (iii) each agent is able to exploit the modularization and extensibility features of the EAF such that each agent is free to internally extend the common argumentation model so it better fits its own needs and knowledge. Concerning latter assumption, it is especially relevant the application of the H_A, H_S and H_M relations so that the agent explicitly states the specialization of its individual EAF model (i.e. EAF_{Ag}) in respect to EAF_c. These relations will provide a minimal common classification of arguments, statements and reasoning mechanisms introduced individually by each agent. Based on these assumptions, we propose the EAF-based negotiation process to be adopted by each negotiating agent.

The negotiation process specifies nine phases (Figure 2).

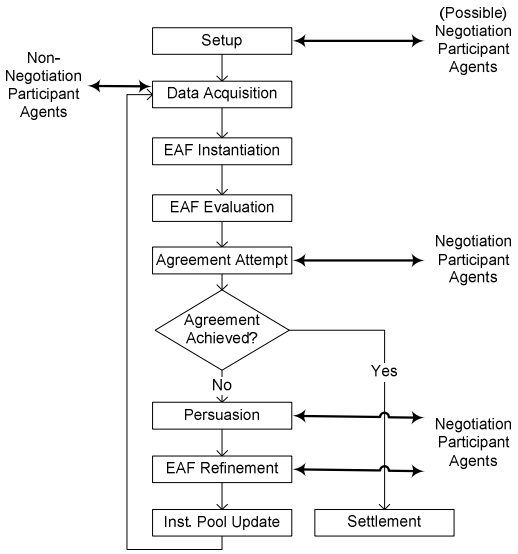

Figure 2. EAF-based negotiation process

3.1 Setup

The Setup phase encompasses a set of domain-dependent interactions between agents such as: (i) the identification of the (possible) negotiation participants, (ii) the identification of the negotiation object, (iii) the identification of which is the community minimal common understanding (i.e. EAF_c) between all participants, (iv) the definition of the required negotiation parameters/constraints such as deadline for achieving an agreement, (v) the specification of the arguments exchanging method used by each agent, (vi) the specification of the negotiation method to compute a possible agreement between participants (e.g. by consensus between all participants or by the majority of participants opinions), (vii) the establishment of special rights for some of the participants, (viii) sharing the data/information that is required by the agents in order to participate in the negotiation. At the end of this phase, the context of the EAF-based negotiation is completely defined and known by all participating agents. Therefore, such context must be uniquely identified and further participants' interactions related with that content must be clearly stated as so. Yet, such context defines a set of constraints called negotiation parameters (i.e. NP). Moreover, each participant creates an instance-pool of its own EAF (i.e. $IP(EAF_{Ag})$) that will capture the argumentation data. Contrary to the other phases, this phase occurs only once.

3.2 Data Acquisition

During the Data Acquisition phase the agent collects, from the environment, a set of data/information (called D_{Ag}) that constitutes the grounds to generate arguments. The agent may rely on a communication process with other agents (non-participating directly in the ongoing negotiation), namely specialized agents on the subject under discussion.

3.3 EAF Instantiation

The goal of the EAF Instantiation phase is to analyze and to process the collected data (i.e. D_{Ag}) in order to add and/or update the instances (e.g. argument-instances) in the respective EAF instance-pool. For that, the agent makes use of one or more data transformation processes whose output is a set of unclassified (or partially classified) EAF_{Ag} instances. Next, those instances are properly (re)classified as required by the EAF. An EAF instances (re)classification process is also needed further in the Instance-Pool Update phase. In that sense, it is envisaged that the instances (re)classification process might be the same in both phases, however that is not mandatory.

3.4 EAF Evaluation

In the EAF Evaluation phase, each agent extracts a *preferred extension*, i.e. a consistent position within EAF_{Ag} which is defensible against all attacks and cannot be further extended without introducing a conflict. According to the agent's $IP(EAF_{Ag})$ one or more possible *preferred extensions* may be extracted. If the EAF-evaluation process extracted more than one *preferred extension* then it is necessary to select one. Notice that the selection criterion has a special relevance during the negotiation process, because it directly defines the public agent's position about the subject under discussion (i.e. its *intentions* and the *beliefs* behind those *intentions*). Given that, instead of a simple criterion such as "selection of the preferred extension that is maximal with respect to set inclusion", a more elaborated selection criterion may take into consideration the *preferred extension* previously selected (if there is any) in order to select, for example, the one that differs less. This phase may occur more than once due to new data/information acquisition and especially due to the exchange of arguments between the agents during the persuasion phase. Thus, any change made to $IP(EAF_{Ag})$ suggest that the agent's consistent position may change, hence requiring a re-evaluation of the *preferred extension* by the agent.

3.5 Agreement Attempt

In the Agreement Attempt phase each participant makes a proposal of agreement to the other agents in order to find out an overall common agreement (called candidate agreement) which can be accepted and further settled by all participants. It comprehends two steps. In the first step, each agent makes its proposal of agreement by exchanging the intentional argument of its *preferred extension* only (called *intentional preferred extension*). As a result of all proposals, two sets of arguments are derived and then shared by all agents: (i) the set of arguments agreed/proposed by all agents ($AgreedArgs$) which represents a candidate agreement and (ii) 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 (i.e. NP) and the content of the $DisagreedArgs$ set. According to the level of satisfaction, the participants must decide to either:

- 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 it was considered that it is not worth keep trying to achieve another candidate agreement. The negotiation ends without an agreement.

3.6 Persuasion

From previous phase it has been identified a set of intentional arguments that are not accepted by at least one participant (i.e. $DisagreedArgs$). In the this phase, each agent, first selects from its *preferred extension* a (sub-) set of arguments supporting or attacking the intentional arguments in $DisagreedArgs$, which will further be exchanged with the opponent agents to persuade them. There are two forms to exchange 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.
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.

The way the arguments are exchanged is defined in the setup phase, and will have implications in next phase.

Yet, independently of the exchanged method, at the end of this phase, each agent has collected a new set of information (ED_{Ag}), corresponding to the received arguments presented by the other negotiating agents.

3.7 EAF Refinement

This phase concerns the refinement of the community's EAF model according to the exchanged arguments and the agents' EAF models. Therefore, if the exchange of arguments does not include exchanging parts of the agent's EAF model, this phase is more difficult and therefore may be skipped. It is not the aim of this description to present an EAF evolution process, nor the agents' reasoning process leading to such evolution. Instead, this description intends to emphasize the ability of the EAF to be extended according the agent's needs, by exploiting the modularization features of the proposed argumentation framework.

3.8 Instance Pool Update

In this phase, the agent reclassifies the ED_{Ag} data according to its EAF_{Ag} applying an instance (re)classification process, which might be the same used in the EAF Instantiation phase. The reclassified data that do not exist into $IP(EAF_{ag})$ is added while duplicated arguments are discarded. Added arguments are taken into consideration by the agent in the next round of proposals. The negotiation process proceeds to the Data Acquisition phase.

3.9 Settlement

The goal of the settlement phase is to transform the candidate agreement into a definitive agreement according to the settlement

parameters of *NP*. Depending of the domain of application and the negotiation object (e.g. a good or a service) as well as the participating partners, the settlement phase can have a varying of sub-functions. In this respect, this phase is seen as an initiator of a set of transactions that must occur after the agreed terms are known in order to fulfill the terms. For example, in an e-commerce scenario, to fulfill an agreement for selling a physical good may imply to carry on logistic and financial services.

4. EXPERIENCES

Since the proposed negotiation approach is domain independent, to carry out some experiments we need to choose a domain of application. We applied the EAF-based negotiation approach to address 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 (i.e. an alignment) between entities of agents' ontologies. Such conflicts arise because each agent may have its own perspective about what are the best correspondences. In that sense, the experiments aim to measure the improvement produced on the accuracy (in terms of precision, recall and f-measure) of the agreed alignment by the negotiation process when compared to each agent's initial proposal, i.e. before the negotiation process runs. For this purpose, we adopted an empirical approach using (i) a set of pairs of publicly available ontologies used in several ontology alignment experiences as, for example, the Ontology Alignment Evaluation Initiative (OAEI) and (ii) for each pair of ontologies a widely accepted reference alignment that will be exploited 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. The reference alignment contains 1402 correspondences (also referred as matches) corresponding to the sum of all correspondences of all reference alignments. We have configured three agents, each one using a distinct set of matching algorithms and a distinct EAF model (extended from a common one).

Table 1 summarizes and characterizes the automatic alignment of each agent before the negotiation process runs. Correct matches are those that exist in the reference alignment.

Table 1. Agents' alignment before the negotiation process

Agent	Matches		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 2 summarizes and characterizes the agreed alignment between each possible pair of agents. It also shows (i) on column "U." the amount of matches under discussion on the beginning of the negotiation process i.e. the agents' contradictory initial position, (ii) on column "U.C" the amount of correct matches under discussion, (iii) on column "R." the amount of matches that even after the negotiation process remain contradictory, (iv) on column "R.C." the amount of correct matches remaining with contradictory position and (v) on column "G.P." the percentage of good persuasion occurred, i.e. one of the agents concede its initial position in favor of the opponent agent's position, and that concession contributes positively for the quality of the achieved agreement.

Table 2. Agreed alignment between agents

Agent	Matches						Accuracy (%)			G.P. %
	P.	C.	U.	U.C.	R.	R.C.	Pr.	Re.	F-M.	
A-B	1294	1243	813	78	308	67	96.1	88.7	92.2	96.4
A-C	1250	1214	200	119	130	90	97.1	86.6	91.6	67.1
B-C	1387	1234	779	75	220	39	89.0	88.0	88.5	82.6

Examination of results shows that independently of the amount of resolved conflicts, the percentage of good persuasion is always high and consequently the negotiation process is beneficial to the overall accuracy of the agreed alignment. Yet, it also perceived that it is very hard for an agent to successfully persuade its opponent to change position about a correct match proposed by its opponent.

5. CONCLUSIONS

This paper describes a novel, generic and domain independent argument-based negotiation process based on the adoption of the Extended Argumentation Framework. Due to the modeling, modularity and extensibility features of 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 (section 3.7). 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).

Experiences in the ontology alignment field show that the adoption of the EAF-based negotiation process leads to a substantial improvement in the quality of the agreed ontology alignment when compared with the intersection of agents' individual ontology alignment. The good persuasion is achieved both by persuading the opponent by accepting a correct match and by rejecting an incorrect match.

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 EAF Update phase.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] R. Moran, *Authority and Estrangement: An Essay on Self-Knowledge*. Princeton University Press, 2001.

[2] P. Maio and N. Silva, *Technical Report: The Extensible Argumentation Framework*. Porto, Portugal: ISEP, 2011.

[3] J. Euzenat and P. Shvaiko, *Ontology Matching*, 1st ed., vol. 1, 1 vols. Heidelberg, Germany: Springer-Verlag, 2007.

[4] D. Walton, "Argumentation Theory: A Very Short Introduction," in *Argumentation in Artificial Intelligence*, Springer Publishing Company, Incorporated, 2009.

[5] M. Bratman, *Intention, Plans and Practical Reason*. Cambridge, MA: Harvard University Press, 1987.

[6] M. Wooldridge, *An Introduction to MultiAgent Systems*, 2nd ed. Wiley, 2009.