A Framework for Arguing from Analogy: Preliminary Results

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Abstract. Human reasoning applies argumentation patterns to draw conclusions about a particular subject. These patterns represent the structure of the arguments in the form of argumentation schemes which are useful in AI to emulate human reasoning. A type of argument schema is that what allow to analyze the similarities and differences between two arguments, to find a solution to a new problem from an already known one. Researchers in the heavily studied field of analogies in discourse have recognized that there is not a full and complete definition to indicate when two arguments are considered analogous. Our proposal presents an initial attempt to formalize argumentation schemes based on analogies, considering a relationship of analogy between arguments. This will contribute to the area increasing such schemes usefulness in Artificial Intelligence (AI), since it can be implemented later in Defeasible Logic Programming (DeLP).

1 Introduction

The ability to solve problems based on previous experience can be considered as an useful tool to develop and integrate to critical thinking. The act of thinking critically involves combining previous experiences with new experiences, finding patterns that follow those experiences, and considering the relationships among those patterns.

In the process of argumentation, information plays a fundamental role in supporting a point of view, making decisions, presenting the views of others, and solving new problems using past experiences. The human-like mechanism developed in computational argumentation research has made a significant contribution to the formalization of common sense reasoning and implementation of useful systems. In a general sense [15,7,2,14], argumentation can be associated with the interactive process where arguments for and against conclusions are offered, with the purpose of determining which conclusions are acceptable. Several argument-based formalisms have emerged, some of them based on Dung's seminal work called Abstract Argumentation Frameworks (AF)[5], others using non-abstract or concrete forms of building arguments [1,7,6,12] leading to the application of these systems in many areas such as legal reasoning, recommender systems and multi-agent systems.

For Walton [18,17], Argumentation Schemes offer the possibility of representing the reasoning mechanisms on a semi-formal way, thus helping in the task of characterizing the inferential structures of arguments used in everyday discourse, particularly in special contexts such as scientific argumentation and AI systems in general. These simple devices capture the patterns of thought and expression from natural language, and contain questions that govern each of these patterns.

A particular type of argumentation scheme corresponds to *Argument from Analogy*, which represents a very common form of everyday human reasoning. In these schemes, two cases are analyzed for similarities and differences between them, using a form of inductive inference from a particular to a particular where the similarities between the cases lead to postulate a further similarity not yet confirmed; for instance, *"I have recently read H.G.Well's 'The Time Machine' and I liked it. Therefore, I will also like 'The War of the Worlds' by the same author"*. It should also evaluate if the perceived differences do not undermine the similarities between them. The argumentation from analogy allows to solve a new case based on already solved cases, or put it in a different way, to use previous experiences to consider a new case.

In this work, we will propose an extension of the abstract argumentation frameworks which allows to represent analogy between arguments determining the similarity degree or difference degree between them. This extension will be called *Analogy Argumentation Framework* ($AnAF$). This extension is motivated in the use of inferential mechanisms of argumentation based in the idea of argument from analogy that, as we said, are used in everyday situations in which a conclusion is obtained based on previous observations.

The paper is organized as follows. In section 2 is presented a brief introduction to argumentation schemes. Then, in Section 3 we introduce the concept of analogy. In Section 4, we present an introduction to argumentation framework. The core contribution of the paper is presented in Section 5 called as *Analogy Argumentation Framework*. Finally, in Section 6 we present the related work associated with the central issue of the work, and in Section 7 we conclude and propose future works.

2 Argumentation Schemes

There are several argumentation schemes proposed by Walton [18] applied to different areas such as in the legal and scientific communities, and in learning environments. These schemes are gaining importance in the field of AI, particularly because they allow the representation of defeasible arguments, *i.e.*, that can be refuted by who receives the argument, who thinks critically in relation to a given position. There are various argumentation schemes proposed by Walton [20], such as arguments coming from experts, from popular opinion, or from signs, among others.

In this paper, we focus on the *Argumentation from Analogy Scheme*. This scheme considers two cases C_1 and C_2 assessing the similarities and differences between them. The defeasible character is introduced by the specific differences between the cases C_1 and C_2. Walton defined three *critical questions* that are appropriate for using the scheme of argument from analogy:

1. Are there differences between C_1 and C_2 that would tend to undermine the force of the similarity cited?
2. Is the feature A true (false) in C_1?
3. Is there some other case C_3 that is also similar to C_1, but in which the feature A is false (true)?

In the words of Walton [18]: "*In general, the first critical question for the argument from analogy tends to be the most important one to focus on when evaluating arguments from analogy. If one case is similar to another in a certain respect, then that similarity gives a certain weight of plausibility to the argument from analogy. But if the two cases are dissimilar in some other respect, citing this difference tends to undermine the plausibility of the argument. So arguments from analogy can be stronger or weaker, in different cases.*"

In a recent work [19], Walton has analyzed different possibilities for this type of schema and has offered his understanding of how the schema integrates with the usage of argument from classification and the argument from precedent when applied in case-based reasoning by the use of a dialogue structure; below, we will summarily discuss these ideas. Next, we will focus on a detailed study of the concept of analogy, and define a relation of analogy between argument entities.

3 The Concept of Analogy

The term *analogy* has been widely studied as to their meaning and usage. Hesse [8], argues that the word is self-explanatory, and that two objects or situations are similar if they share some properties and differ in others. Walton [19] agrees with this perspective adding that two things are similar when they are visibly similar or they look similar. As to how to determine when two arguments are similar, Hesse uses a comparison between arguments based on the use of mathematical proportions. On the other hand, in a refinement of Hesse's idea, Walton points out that it is not easy to clearly define the comparison between arguments, as this requires interpreting the similarities and differences between them at various levels.

Offering another view, Carbonell [3] proposes a technique based on how we solve problems. This technique takes into account information from previous experience, which is useful for solving a new problem, as long as both occur in similar contexts; that is, the context of the problem determines a set of constraints under which the proposed solution is feasible. In [16], Sowa argues that it is possible to make a comparison between arguments, establishing a function of similarity or correspondence between them; and, by using another function, referred to as the estimation function, it is possible to find the differences between the arguments. In a parallel effort, in [4] Cecchi *et al.* characterized and formalized relationships that capture the behaviour of a preference criterion among arguments; while this does not refer specifically to arguments from analogy, shows the usefulness in approaching the analogy between two arguments as a binary relationship.

These questions have received different answers and remains the focus of different research lines. Briefly, two objects or situations are analogous when they have some similar properties, maintaining other properties different. The similarity is then related to the properties shared between two objects or situations being compared. Following previous work, our proposal is to consider the analogy between two arguments A and B relaying on the following items defined next.

Definition 1 (Analogy Elements). *Given a set AR of arguments, we introduce:*

1. *a* constraint set*, denoted as Δ, contains the features governing the comparison of arguments in a given situation.*
2. *a* similarity degree *between two arguments A and B, denoted as $\alpha_\Delta(A, B)$, as a function: $\alpha_\Delta : AR \times AR \rightarrow [0, 1]$,*
3. *a* difference degree *between two arguments A and B, denoted as $\beta_\Delta(A, B)$, as a function: $\beta_\Delta : AR \times AR \rightarrow [0, 1]$,*

furthermore, for all $A, B \in AR$, it holds (1) $\alpha_\Delta(A, B) = \alpha_\Delta(B, A)$, (2) $\beta_\Delta(A, B) = \beta_\Delta(B, A)$, *and* (3) $\alpha_\Delta(A, B) + \beta_\Delta(A, B) = 1$.

The set Δ specifies the features that are significant to consider to establish whether two arguments are analogous or not. The content of this set is heavily dependent on the domain where the arguments are considered; thus, this is a semantic concept from which we will abstract away introducing the tools that will handle these features building the infrastructure for arguing from analogy. In the same way as Δ, the two functions α_Δ and β_Δ are dependent on the domain of application; therefore, although they remain unspecified in the formalization, a concrete definition must be given when implementing the framework. It is important to remark that in this initial approach, as the definition establishes, there is no difference in comparing A with B or B with A. This decision of not assigning preference to the features is a simplifying one, taken in the spirit of analyzing the simplest problem. In the future evolution of these ideas, we will to consider some form of preference over Δ's elements, and this preference will help in the comparison in a natural way introducing different possibilities.

Naturally, if between the arguments being compared the similarity degree is greater than the difference degree under the constraint set, it can be considered that the arguments are analogous; otherwise, differences prevail and they are considered as not analogous. Observe that the similarity degree and the difference degree are mutually dependent, *e.g.*, if the similarity degree between two arguments is 0.7, then the difference degree between them is 0.3. The following definition formalizes the analogy relation between arguments.

Definition 2 (Analogy Relation). *Let AR be a set of arguments and* Δ *be a constraint set. An* analogy relation*, denoted* Γ_Δ*, is defined as a binary relation on AR under the constraint set* Δ*, where the relation* Γ_Δ *is such that* $\Gamma_\Delta \subseteq AR \times AR$ *and satisfies the constrains of* Δ*, where* $(A, B) \in \Gamma_\Delta$ *iff* $\alpha_\Delta(A, B) > \beta_\Delta(A, B)$*, i.e., the similarity degree between them is greater than their difference degree.*

From the previous definition of analogy relation Γ_Δ, we can establish the following properties hold for analogy when arguments are compared over the same features or properties:

- *Reflexive*: $A \ \Gamma_\Delta \ A$. Any argument is analogous to itself.
- *Symmetric*: If $A \ \Gamma_\Delta \ B$, then $B \ \Gamma_\Delta \ A$. The analogy relation is symmetric by definition, *i.e.*, the analogy between arguments is established from the similarity between both, under a constraint set. This explains why the analogy relation is symmetric and is not asymmetrical.
- *Transitive*: If $A \ \Gamma_\Delta \ B$ and $B \ \Gamma_\Delta \ C$, then $A \ \Gamma_\Delta \ C$. The arguments A and B are similar according to the constraint set defined, the same occurs between the arguments B and C, thus A and C are similar and relation is transitive.

That is, the analogy relation between arguments under a given constraint set is an equivalence relation under that constraint set, and each equivalence class will contain all the arguments that have identical features in the frame of Δ. Also notice that the analogy relation is not equality since two argument that are analogous under a constraint set might no be analogous under a different constraint set. The definition of the analogy relation between arguments under a constraint set just introduced, will allow us to reformulate the questions for guiding the argumentation from analogy scheme, in the following way:

1. Are A and B analogous? Is $(A, B) \in \Gamma_\Delta$?
2. Are there differences between A and B that would tend to undermine the force of the similarity cited? Is $\alpha_\Delta(A, B) > \beta_\Delta(A, B)$?

4 Abstract Argumentation

Dung [5] introduced Abstract Argumentation Frameworks (AF) as an abstraction of a defeasible argumentation system. In an AF, an argument is an abstract entity with unspecified internal structure, and its role in the framework is solely determined by the attack relation it keeps with other arguments; thus, an AF is defined by a set of arguments and the attack relation defined over it.

Definition 3 (Argumentation Framework [5]). *An argumentation framework (AF) is a pair described as* $\langle AR, Attacks \rangle$*, where AR is a set of arguments, and the binary relation* $Attacks \subseteq AR \times AR$*.*

When it happens that $(A, B) \in Attacks$, we say that A attacks B, or that B is attacked by A. Likewise, extending the relation of attack, we will say that the set S attacks C when there exists at least an argument $A \in S$, such that

$(A, C) \in Attacks$. Given an AF, intuitively $A \in AR$ is considered *acceptable* if A can be defended of all its attackers (arguments) with other arguments in AR; this is formalized in the following definitions [5].

Definition 4 (Acceptability). *Let $AF = \langle AR, Attacks \rangle$ be a framework.*

- *A set $S \subseteq AR$ is said* conflict-free *if there are no arguments $A, B \in S$ such that $(A, B) \in Attacks$.*
- *$A \in AR$ is* acceptable *with respect to $S \subseteq AR$ iff for each $B \in AR$, if B attacks A then there exists $C \in S$ such that $(C, B) \in Attacks$; in such case it is said that B is attacked by S.*
- *A conflict-free set S is* admissible *iff each argument in S is acceptable with respect to S.*
- *An admissible set $S \subseteq AR$ is a* complete extension *of AF iff S contains every argument acceptable with respect to S.*
- *A set $S \subseteq AR$ is a* grounded extension *of AF iff S is a complete extension that is minimal with respect to set inclusion.*

We will now extend the Dung's framework introducing the possibility of taking in consideration the similarities and differences between arguments.

5 Analogy Argumentation Framework

Recently, the field of application of argumentation has been expanding, with the interesting addition of the research on argumentation schemes; however, still there is need to further formalize the structure of these schemes. Here, we will make a first approximation to this formalization through extending AFs to *Analogy Argumentation Frameworks (AnAF)*, introducing the consideration of the analogy between arguments in the well-known argument from analogy scheme, by representing the notions of similarities and differences between arguments.

When considering analogy among the set of arguments is natural, and intuitively appealing, to requiere two things: (1) that arguments that are analogous do not attack each other, and (2) if an argument attacks another, then any argument analogous to the attacker should be an attacker to same argument. This can easily formalized by taking advantage of the analogy relation that happens to be an equivalence relation. Let $[A] = \{X \in AR \mid X \Gamma_\Delta A\}$ be the class of arguments equivalent to A and AR_{Γ_Δ} the quotient set of AR by Γ_Δ.

Definition 5 (Nonconflicting Class). *Given an $AF = \langle AR, Attacks \rangle$, and an analogy relation Γ_Δ defined over AR. Let $[A] \in AR_{\Gamma_\Delta}$, $[A]$ is said to be a* nonconflicting class *iff there is no pair of arguments $X, Y \in [A]$ such that $(X, Y) \in Attacks$. The AR is said to be Γ_Δ-conformant iff all classes in the quotient set AR_{Γ_Δ} are non-conflicting.*

Definition 6 (Class Attack Relation). *Given an $AF = \langle AR, Attacks \rangle$, and an analogy relation Γ_Δ defined over AR. Let $[A] = \{X \in AR \mid X \Gamma_\Delta A\}$ be the class of arguments equivalent to A and AR_{Γ_Δ} the quotient set of AR by Γ_Δ. We say that Attacks is a class attack relation over AR_{Γ_Δ} iff when $A, B \in AR$,* *and* $(A, B) \in Attacks$ *it happens that every argument* $X \in [A]$ *attacks every argument* $Y \in [B]$*.*

Definition 7 (AnAF). *Given* $AF = \langle AR, Attacks \rangle$*, and an analogy relation* Γ_Δ *defined over AR. An Analogy Argumentation Framework (AnAF) is a 3-tuple* $\Theta = \langle AR, Attacks, \Gamma_\Delta \rangle$ *where AR is a set of arguments, and Attacks is a* Γ_Δ*-conformant, class attack relation.*

These definitions follow the intuitions expressed in (1) and (2) above.

Given an $AnFA$, an argument A is considered *Analogy-acceptable* if it can be defended of all its attackers (arguments) with other arguments in AR.

Definition 8 (Analogy Acceptability). *Let* $\Theta = \langle AR, Attacks, \Gamma_\Delta \rangle$ *be an AnAF. The acceptability of* $S \subseteq AR$ *is given by the following conditions:*

- $S \subseteq AR$ *is an Analogy-Conflict-Free set iff there are no arguments* $A, B \in S$ *such that* $(A, B) \in Attacks$*.*
- $A \in AR$ *is an Analogy-Acceptable with respect to* $S \subseteq AR$ *iff for each* $B \in AR$*, if* B *attacks* A *then exist* $C \in S$ *such that* B *is attacked by* C*.*
- *An Analogy-Conflict-Free set* S *is Analogy-Admissible iff each argument in* S *is Analogy-Acceptable with respect to* S*.*
- *An Analogy-Admissible set* $S \subseteq AR$ *is an Analogy-complete extension of* Θ *iff* S *contains each argument that is Analogy-Acceptable with respect to* S*.*
- $S \subseteq AR$ *is the Analogy-grounded extension of* Θ *iff* S *is an Analogy-complete extension that is* $\subseteq$*-minimal.*

Example 1 *Consider a scenario where an agent must decide whether it is riskier to invest in a real estate property or to invest in gold bullion, to reach a decision the agent ponders these arguments:*

A: I should invest my savings in real estate because they do not depreciate quickly, and this leads financial safety.

B: It is better to invest in gold bullion because it does not deteriorate, and it does not require maintenance as real estate does. It is not wise to invest in real estate because they lose value in many ways.

C: Investing in gold bullion is expensive because you have to store them in a safekeeping place. Land does not deteriorate, does not depreciate fast, does not require a place to store and provide financial reinsurance. I should not invest in gold bullion.

D: Buying land is a good way to invest whenever you carefully look for a place. Land does not devalue easily.

E: Buying foreign currency is an investment of unpredictable results because it depends on the global economy.

Let $\Theta = \langle AR, Attacks, \Gamma_\Delta \rangle$ *be an AnAF, where:*$AR = \{A; B; C; D; E\}$*,* $Attacks = \{(B, A); (C, B); (B, D)\}$ $\Gamma_\Delta = \{(A, C); (D, A); (D, C); (C, A); (A, D); (C, D)\}$*, and* Δ *is "Invest the savings into something that is not quickly devalued", and the similarity and difference degrees are represented in table 1.*

Some of analogy-conflict-free set are: $S_1 = \{A\}$*,* $S_2 = \{A; C\}$*,* $S_3 = \{A; C; D\}$*,* $S_4 = \{B\}$ *and* $S_5 = \{B\}$*. Note, for example, the set* $S_6 = \{A; E\}$ *is a conflict-free, but is not an analogy-conflict-free given that there is not an analogy relation*

$\alpha_\Delta(B,A) = 0$ $\beta_\Delta(B,A) = 1$	$\alpha_\Delta(C,B) = 0$ $\beta_\Delta(C,B) = 1$	$\alpha_\Delta(A,E) = 0$ $\beta_\Delta(A,E) = 1$	$\alpha_\Delta(B,D) = 0$ $\beta_\Delta(B,D) = 1$	$\alpha_\Delta(C,E) = 0$ $\beta_\Delta(C,E) = 1$
$\alpha_\Delta(A,C) = 1$ $\beta_\Delta(A,C) = 0$	$\alpha_\Delta(D,A) = 1$ $\beta_\Delta(D,A) = 0$	$\alpha_\Delta(B,E) = 0$ $\beta_\Delta(B,E) = 1$	$\alpha_\Delta(D,C) = 1$ $\beta_\Delta(D,C) = 0$	$\alpha_\Delta(E,D) = 0$ $\beta_\Delta(E,D) = 1$

Fig. 1: Coefficients Table

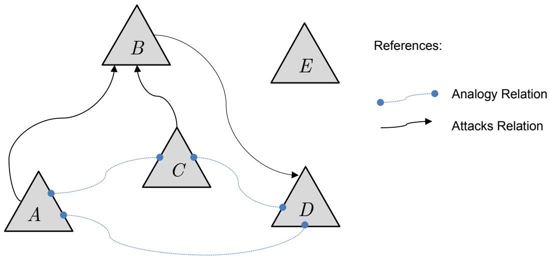

Fig. 2: Example for AnAF

between them on the constraint set considered.
The argument $A \in AR$ is Analogy-Acceptable with respect to S_3, since $B \in AR$ and $(B, A), (C, B) \in Attacks$, and $C \in S_3$. Additionally, $(C, B) \notin \Gamma_\Delta$ and $(A, C) \in \Gamma_\Delta$. The argument $B \in AR$ is not Analogy-Acceptable because $(C, B) \in Attacks$ and there is no an argument that attacks C.
The set S_3 is an Analogy-Admissible because each argument in S_3 is Analogy-Acceptable in S_3. Additionally, S_3 is an Analogy-complete extension of Θ, and S_3 is an Analogy-grounded extension of Θ.

6 Related Works

Few studies exist formalizing the argumentation schemes proposed by Walton. However, there are several extensions of Dung's framework that are inspiring for this paper. Prakken [12] proposed Argumentation Systems with Structured Arguments, which used the structure of arguments and external preference information to define the a defeat relation. In this paper, we use the term "defeat" instead of the "attack", because defeat allows to considerer an attack relation plus preferences. Regarding argumentation schemes, Prakken [13] proposes that modeling reasoning using argumentation schemes necessarily involves developing a method combining issues of non-monotonic logic and dialogue systems. Nielsen *et al.* [11] claim that Dung's framework is not enough to represent argumentation systems with joint attacks, and they generalize it allowing a set of arguments to attack on a single argument. Modgil [10] also extends Dung's framework, preserving abstraction and expressing the preference between arguments. To do this, incorporates a second attack relation that characterizes the preference between arguments. Regarding to preference relation between arguments Cecchi*et al.* [4] defined this as a binary relation considering two particular criteria, specificity and equi-specificity, together with priorities between rules, defining preferred arguments and incomparable arguments.

In regards specifically to formalizing argumentation schemes, Hunter [9] presented a framework for meta-reasoning about object-level arguments allowing the presentation of richer criteria for determining whether an object-level argument is warranted. These criteria can use meta-information corresponding to the arguments, including the proponents and their provenances, and an axiomatization using this framework for reasoning about the appropriated conduct of the experts that introduce them. He shows how it can conform to some proposed properties for expert-based argumentation describing a formal approach to modelling argumentation providing ways to present arguments and counterarguments, and evaluating which arguments are, in a formal sense, warranted. He proposed a way to augment representation and reasoning with arguments at the object-level with a meta-level system for reasoning about the object-level arguments and their proponents. The meta-level system incorporates axioms for raising the object-level argumentation to the meta-level (an important case is to capture when an argument is a counterargument for another argument), and meta-level axioms that specify when proponents are appropriated for arguments. The meta-level system is an argumentation system to the extent that it supports the construction and comparison of meta-level arguments and counterarguments.

7 Conclusions and future works

Human reasoning applies argumentation patterns to draw conclusions about a particular subject. These patterns represent the structure of the arguments in the form of argumentation schemes which are useful in AI to emulate human reasoning. Argumentation schemes are a semiformal way of representing reasoning patterns. In this paper we presented an extension of Dung's frameworks, called *Analogy Argumentation Framework (AnAF)*, which allows to consider the similarity and difference degrees between two arguments in the context of an analogy relation. The analogy between arguments allows to approach the solution of a new case based on already solved cases, or put it in another way, to re-use previous experiences. The analogy relation represents in this proposal a form of a preference between arguments. As work in progress, we analyzed and studied the extensions of the classical semantics proposed by Dung within this new framework. It seems also necessary to formalize other argumentation schemes [20].

As future work, we will develop an implementation of the application of *AnAF* in the existing Defeasible Logic Programing system [1] as a basis. For doing that we will decrease the level of abstraction studying the internal structure of the arguments. To get the similarity degree between arguments involves implementing a mapping function between them, subject to a given constraint set, while determining the difference degree requires to implement a function to estimate differences between the arguments in question, subject to the same constraint set. The similarities or differences between arguments is in fact to compare premises, conclusions or inference mechanisms between arguments. The result-

[1] See http://lidia.cs.uns.edu.ar/delp

ing implementation will be exercised in different domains requiring to model analogy between arguments.

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