Introducing a Context-Aware Scheme in an intelligent reasoning process

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Abstract. Several investigations have been developed around analogies based reasoning in different domains, however the analogy between arguments has not been deeply explored. A semiformal way to express these patterns of reasoning were proposed by Walton, through argument schemes from analogy. From this, it is possible to propose computable approximations for comparing arguments. In this paper we introduce a formalism based on the comparison of arguments through *descriptors* or labels which describes an aspect that the argument refers to. This formalism allows us classifying similar arguments considering the natural descriptors of them, in a specific context.
Keywords: Analogies Based Reasoning, Argumentation Scheme, Descriptors, Context Domain.

1 Introduction

The Argument from Analogy [30, 19] represents a very common form of everyday human reasoning. Briefly speaking, two cases are analyzed for similarities and differences between them, using a form of inductive inference where the similarities between the cases lead to postulate a further not yet confirmed similarity. The argumentation from analogy allows to solve a new case based on already solved cases. Numerous investigations have been developed around analogies based reasoning, which are based on establishing the similarities and differences between a known object -that is part of knowledge base of agents- and another new but which has certain known aspects [20, 26]. In multi-agents systems domain, when an intelligent agents need to solve a certain problem or take a decision, it is common for them to seek into their knowledge base for solutions from previous similar problems, where the context information fits both the new and the known problem. This reasoning process is guided by thought patterns and involves an argumentation process, *i.e.*, a process by which reasons are given in favour of a particular conclusion.

The analogy between arguments has not been deeply explored. Any comparison process requires the definition of the context in which such comparison acquires significance. Meanwhile, as the field of Artificial Intelligence (AI) carries out research in computational argumentation to achieve useful systems based on common sense, it seems desirable and reasonable to try to formalize the analogy between arguments. In general, this context is formed by conditions or variables that govern the comparison process, all of which have different importance degrees and need to be ordered to carry out the process in an effective manner. Consider the following situation where a person needs a recommendation about edible seeds intake being beneficial to improve its health. The recommendation system compare the common properties of the edible seeds, their benefits, and contraindications. To accomplish this, the system's reasoning process must find items to compare alternatives, *i.e.*, some common descriptors to the options under consideration. This example describes a particular pattern of reasoning that is used in order to reach a goal or a conclusion. This pattern of reasoning was called *Argument from Analogy*, and have been expressed in a semiformal way by Walton [31, 30] using a set of critical questions.

In a general sense, argumentation can be associated with an interactive process where arguments for and against conclusions are offered with the purpose of determining which conclusions are acceptable [27]. Several argument-based formalisms have considered an argument like as abstract entity without internal structure [11, 9], while other works that specify concrete forms of building arguments [3, 24, 12]. In addition, there exist some argumentative formalisms that represent the attributes associated to arguments providing more information to determine arguments acceptability [2, 8, 5]. However, these formalisms do not deal with the problem of classifying similar arguments considering the natural descriptors inherent to each argument. In this work, we will propose an *Argumentation Scheme* that that allows to considerer the context of comparison between arguments, based on a set of descriptors that are common to the arguments that are being analyzed. In this way, we will determine and represent analogies between arguments. This paper is structured as follows: a brief introduction to the *analogy concept* is presented in *Section* 2. In *Section* 3, we review the Argumentation Scheme proposed by Walton and, in *Section* 4, contains the core contribution of the paper, there the *Context-Aware Scheme* is formally presented. Finally, in *Section* 5 we present the relevant related work, the conclusions and future work.

2 The Concept of Analogy

The term *analogy* has been widely studied as to their meaning and usage [13, 23]. Hesse [15] argues that the word is self-explanatory and that two objects or situations are similar if they share some properties and differ in others, and put forward that the analogy is a concept inherent in the modelling process, between a portion of the real world and its model or description, as a relationship that finds similarities and differences between both. Walton [30] agrees with

this perspective adding that two things are similar when they are visibly similar or they look similar. Gentner [13] linked the concept of analogies with the representation of the agent's knowledge through the pattern's repetition. First, these patterns should be identified to find relations of correspondence with new situations. Then, it is important to perform a mapping of domains so that these relations of correspondence do not produce a fallacious reasoning. Under this meaning the analogy is considered as a *process* which recovers information from a known situation to compare it with a new one and evaluate whether to apply the same solution according to the structure of the both situations. As to how to determine when two arguments are similar, 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 [7] proposes a technique based on how we solve problems. This technique takes into account previous experience information useful for solving a new problem, as long as both occur in similar contexts. In [28], Sowa argues that it is possible to make a comparison between arguments establishing a function of similarity or correspondence between them. In a parallel effort, Cecchi *et al.* in [10] characterized and formalized relationships that capture the behavior of a preference criterion among arguments; while this does not refer specifically to arguments from analogy, it shows the usefulness in approaching the analogy between two arguments as a binary relation.

Considering the variety of concepts presented, we can say that the analogy is a process that involves the comparison between two entities, for example, objects that look similar, cases, or two arguments in which similarities and differences are interpreted. The critical component in this process is the definition of the conditions under which carry out such comparison. Clearly, the analogical comparison process have received different answers and remain the focus of different research lines. The similarity is related to the properties shared between two objects or situations being compared. However, the comparison of two arguments depends on the agent's perception, which can be influenced by the agent's beliefs, goals, or external variables. All these factors are considered as a context that governs the mapping of two arguments in order to establish similarities and differences between them. The intuition that we have just presented is essential to define a *context-aware scheme* which is based on the argumentation *scheme from analogy* proposed by Walton [31, 30], to which we will refer below.

3 Argumentation Schemes from Analogy

A more applied perspective referring to the pattern of reasoning which appeal to analogies addressed by Walton [31, 30], who proposed an Argumentation Scheme from Analogy consist of a set of questions, premises and conclusions that describe a pattern of human thought [29]. Specifically, the pattern of reasoning based on analogies. compares two situations $\mathtt{C}_1$ and $\mathtt{C}_2$ (or cases, as Walton refers to them in the setting of law) to find similarities and differences between them. In this pattern of thought, $\mathtt{C}_1$ is the *source case or known case* and $\mathtt{C}_2$ is the *target case*

or new case [31]. Two cases may be similar in a given context, but they may be different in another. The general pattern of this scheme is presented bellow [31]:

- *Similarity premise:* $\mathtt{C}_1$ is similar to $\mathtt{C}_2$ (Generally)
- *Base premise:* A proposition A is true (false) in $\mathtt{C}_1$
- *Conclusion:* A is true (false) in $\mathtt{C}_2$

The defeasible character is introduced by the specific differences between $\mathtt{C}_1$ and $\mathtt{C}_2$. Walton defined three *critical questions* that are appropriate for using the scheme of argument from analogy:

1. Are there differences between $\mathtt{C}_1$ and $\mathtt{C}_2$ that would tend to undermine the force of the similarity cited?
2. Is the feature **A** true (false) in $\mathtt{C}_1$?
3. Is there some other case $\mathtt{C}_3$ also similar to $\mathtt{C}_1$, but in which the feature **A** is false (true)?

Walton [30] analyzed different possibilities for this type of schema, for example the usage of argument from classification and the argument from precedent applied in case-based reasoning by the use of a dialogue structure. Another representation is detailed by [22] that considers a relationship in which the objects are instantiated as arguments that maintain an analogical proportion, and that can be expressed as a differs from b as c differs from d, either, a is similar to b as c is similar to d, where a, b, c, and d are entities or situations of any kind including arguments. In both cases, the representation schemes refer to the comparison of situations, entities, or cases that may implicitly contain arguments, where a context constraint plays a determinant role but it is not explicitly defined. Then, we propose below a definition of a *context-aware scheme* that allows us to compare two arguments with the intention of find similarities and differences between them. This approach is based on the exhaustive definition of *constraint set* or *context constraint* inherent of the comparison process between arguments.

4 A Context-Aware Scheme

An alternative to define the analogy relation between two arguments as a computable approximation, is to make the comparison based on a *set of descriptors* associated with the arguments. The use of these descriptors will allow to establish of similarity and difference degree between the arguments into account and formalize an argumentation schemes. We will develop these insights below, considering the following motivation example previously.

Example 1 *Consider the following set of arguments:* $\mathcal{A} = \{\mathsf{A}, \mathsf{B}, \mathsf{C}, \mathsf{D}\}$ *where:*

A *To incorporate chia seeds to your diet is a healthy choice since they are rich in vegetal fats, proteins, antioxidants, and minerals. This seeds helps to reduce conditions such as oxidative stress.*

B *Amaranth seeds provide vitamin A, E, from the B group, calcium, iron, and phosphorus. So this seeds help us in preventing deficiency anemia.*

C *Sesame seeds provide high quantity of calcium, antioxidants, fatty acids, and proteins. Therefore, to ingest sesame seeds is important in preventing osteoporosis.*
D *Chia seeds are harmful to hypotensive individuals because it lowers blood pressure. Therefore, it is not always healthy to incorporate them into the daily diet.*

We want to propose a method that allows to determine the set of similar arguments among themselves, according to a given context. In general, this method consists of the following four stage: (*i*) *Specification of argument's descriptors*; (*ii*) *Setting the context constraint based on argument's descriptors*; (*iii*) *Definition of a preference relation over the context constraint*; and (*iv*) *Computing similarity quotient among the arguments being compared*. Next, we describe each stage of this procedure, in order to clarify the proposed reasoning process.

4.1 Specification of Argument's Descriptors

The set of argument's descriptors is constituted by words or a labels describing aspects that the argument is referring to. In this sense, we assume the existence of a universe of descriptors denoted with $\mathcal{D}$, where the set of descriptors associated with an argument A is denote with $desc(\mathsf{A})$ such that $desc(\mathsf{A}) \subseteq \mathcal{D}$.

Example 2 *An example of a universe of descriptors for a nutritional/health related knowledge base that contains the argument set A of the Example 1 could be the set* $\mathcal{D} = \{type\_of\_food, health\_benefits, dietary\_contribution, health\_risks\}$. *Given the Argument* A *we could specify the following descriptors:* $desc(\mathsf{A}) = \{type\_of\_food, health\_benefits\}$ *stating that the arguments refer to a particular type of food, specific contributions to a diet, and the benefits of its consumption to ones' health. From the perspective of analogical proportion argument* A *is similar to argument* B *as the argument* C *is the argument* D*, if we consider that the first two refer to ingestion of eggs while the latter two refer to the intake of seeds.*

Find the descriptors embedded in the arguments involves technical practice of argumentation mining which are being widely investigated [17, 18, 21].

4.2 Setting the Context Constraint

A context constraint specifies conditions under which arguments can be compared. In this sense, two arguments can only be compared if they share at least some descriptors. We can present the following definition, based on the comparability of two arguments. In the rest of the paper, whenever there is no ambiguity, we will refer to context constraints simply as contexts.

Definition 1 (Context Constraint) *Let* $\mathcal{D}$ *a set of descriptors. A context constraint, denoted as* Δ*, is a subset of* $\mathcal{D}$ *that represent the relevant aspects to perform the arguments comparison in a particular domain.*

Example 3 *Continuing with the setting of the Example 2, the elements defined in* $\mathcal{D}$ *could be instantiated as follows. Let* $\Delta_1 = \{type\_of\_food, dietary\_contribution\}$ *be a context indicating that two arguments can be compared in this environment whenever they refer to a type of food and dietary contributions of this food. Other contexts could be* $\Delta_2 = \{health\_benefits\}$.

We can observe that there is at least one item in Δ which prevails in the comparison between two arguments (in this example could be *type_of_food*), while there are other elements in Δ which indicate properties that can take the null value (for example, *health_benefits*). This implies that we must establish a preference relation among the elements of Δ to compute this type of information. We will refer to them below.

4.3 Definition of a Preference Relation over the Context

When the context has more than one descriptor, it is necessary to establish some order among elements in order to carry out the comparison of the arguments more accurately, which can be expressed as follows:

Definition 2 (Preference between Descriptors) *Let $\nu_1, \nu_2 \in \Delta$ be descriptors of arguments. Let $\mathfrak{pref}$ be a preference relation between ν_1 and ν_2. We says that $(\nu_1, \nu_2) \in \mathfrak{pref}$ iff ν_1 is a* prevailing condition *to make the comparison between arguments, i.e. ν_1 cannot take the value null, and there is no $\nu_2 \in \Delta$ such that ν_2 has the opposite meaning to ν_1 given to ν_1 is a fundamental descriptor.*

This preference relation can be specified in various ways according to the domain being modelled. For example, weights or probability values can be assigned to the descriptors, or a partial order relation between descriptors could be established. Once descriptors, the context, and the preference relation between descriptors were defined, we can compute the similarities and differences between two arguments. However, it should be noted that descriptors take values for an argument in particular. Thus, we should consider some mapping function μ that establishes the relation between each descriptor in Δ and the set of concepts to which the argument is referring to– these concepts could, for instance, be just words in natural language or more complex concepts in an ontology. We will not focus on formalizing these concepts; however, intuitively, we can say that using the mapping function it is possible obtain the set of words or concepts that a given argument $\mathsf{A} \in \mathcal{A}$ refers to. As an example of how to formalize such a function, it could be based on the *intensional relational structure, or conceptualization* presented in [14] as a triple consisting of a universe of discourse, a set of possible worlds or values that characterize a system, and a set of conceptual relations on two previous ones. With all these elements in place, we can compute the similarities between two arguments, which will detail below.

4.4 Computing Similarity Quotient among Arguments

To decide if two arguments are analogous, we propose to evaluate the values that take their descriptors. If the descriptors with matching values exceeds the descriptors with different values, and the prevailing conditions are fulfilled, the arguments are considered analogous. Otherwise, the arguments are considered different. This involves calculating a similarity quotient between the values of argument's descriptors that are being compared.

Definition 3 (Similarity Quotient) *Let* $\mathsf{A}, \mathsf{B} \in \mathcal{A}$ *be two arguments to be compared,* Δ *be a context orderer by a preference relation pref, and* μ *be a mapping function. We define the similarity quotient* $\alpha_\mu(\mathsf{A}, \mathsf{B})$ *as:*

$$0 \leq \frac{\mid \mu(\mathsf{A}) \cap \mu(\mathsf{B}) \mid}{\mid \overline{\mu(\mathsf{A}) \cap \mu(\mathsf{B})} \mid} \leq 1$$

where $\mid \overline{\mu(\mathsf{A}) \cap \mu(\mathsf{B})} \mid$ *must be different to* 0.

A null divisor in our case means that if the arguments under comparison do not have differences, it makes no sense consider an analogy between them, but rather an identity in the context used.It is important to remark that in this approach, there is no difference in calculating $\alpha_\mu(\mathsf{A}, \mathsf{B})$, or $\alpha_\mu(\mathsf{B}, \mathsf{A})$, *i.e.*, we assume that similarity quotient is symmetric. With these elements in place, we can now propose a notion of analogy between arguments. Intuitively, we considerer that two arguments A and B are *analogous* iff the similarity quotient is is greater than 0.5. According to previous definitions, this implies that the arguments being compared under a interest context and and all the prevailing conditions are fulfilled. The following definition formalizes the notion analogy relation between arguments that we adhere to in this work, and it is a refining of the one presented in [6].

Definition 4 (Analogy Relation) *Let* $\mathcal{A}$ *be a set of arguments,* Δ *be a context orderer by a preference relation, and* α_μ *be a similarity quotient between two arguments in* $\mathcal{A}$*. An* analogy relation*, denoted* $\mathbb{R}_\Delta$*, is defined as* $\mathbb{R}_\Delta \subseteq \mathcal{A} \times \mathcal{A}$*, where* $(\mathsf{A}, \mathsf{B}) \in \mathbb{R}_\Delta$ *iff* $\alpha_\mu(\mathsf{A}, \mathsf{B}) > 0.5$*, all the prevailing conditions are fulfilled, and verifies that: (i)* $\mathbb{R}_\Delta(\mathsf{A}, \mathsf{B}) = \mathbb{R}_\Delta(\mathsf{B}, \mathsf{A})$*; (ii)* $\mathbb{R}_\Delta(\mathsf{A}, \mathsf{A}) = 1$*; and (iii)* $\mathbb{R}_\Delta(\mathsf{A}, \mathsf{B}) = 0$ *Iff* $\mu(\mathsf{A}) \cap \mu(\mathsf{B}) = \emptyset$.

Example 4 *Picking up the* Example 3*, we need to center on the value that each of the descriptors takes for every argument, according to the context* Δ*. For this comparison, we take a context* $\Delta = \{dietary\_contribution\}$*. In this case, the similarity quotient regarding* Δ *could be calculated for* A*,* B *and* C *in* $\mathcal{A}$*, using the number of descriptors of the arguments* A *and* C *who take the same value, over the number of descriptors of those arguments that take different values. In the same way we proceeded with the arguments* B *and* C*. Arguments* A *and* C *are analogous in this context because* $\alpha_\mu(\mathsf{A}, \mathsf{C}) = 0.5$*. However, arguments* B *and* C *are not analogous in this context, due to* $\alpha_\mu(\mathsf{B}, \mathsf{C}) = 0.33$.

Note that we make no assumption about the relation to be transitive; this is, if $\mathsf{A}\ \mathbb{R}_\Delta\ \mathsf{B}$ and $\mathsf{B}\ \mathbb{R}_\Delta \mathsf{C}$, then not necessarily must the case that $\mathsf{A}\ \mathbb{R}_\Delta \mathsf{C}$. It may happen that $\alpha_\mu(\mathsf{A}, \mathsf{B})>0.5$, $\alpha_\mu(\mathsf{B}, \mathsf{C})>0.5$ and $\alpha_\mu(\mathsf{A}, \mathsf{C})<0.5$. Clarified the meaning of the analogy between arguments, we can define below an argumentation scheme based on context information.

Definition 5 (Context-Aware Scheme) *Let* $\mathcal{A}$ *be a set of arguments,* Δ *be a context orderer by a preference relation, and* α_μ *be a similarity quotient between two arguments* A *and* $\mathsf{B} \in \mathcal{A}$*. The context-aware scheme is defined as:*

- *Similarity premise:* A *is analogous to* B

- *Base premise:* $\mu(\mathsf{A}) = P$*, where* P *is the descriptor's value for* A
- *Conclusion:* $\mu(\mathsf{B}) = P$*, , where* P *is the descriptor's value for* B.

In this scheme, the similarity premise implies that the analogy relation between two arguments is grater than the difference between them, considering a orderer context. The comparison between arguments is given to for the prevailing conditions and the rest of the descriptors which are interesting in the context. The defeasible character is introduced by the context under which the arguments are compared:

1. Exist Δ' that would tend to undermine the force of the analogy cited?
2. Is the descriptor $\mathbf{P} \in \Delta'$ true and is $\mathbf{P}$ a prevailing condition?

When considering the original critical questions defined by Walton, the similarity between two cases can be questioned. In the context-aware scheme, the analogy is established considering a specific context for comparison. The first thing that it is possible to question is whether the comparison context that has been considered is the right. Then, its possible to question about the preference relation in the context.

Example 5 *Continuing the example that we have been developing, we have:*

- *Similarity Premise:* A *is analogous to* C*, considering* $\Delta = \{type\_of\_food\}$.
- *Base premise:* $\mu(\mathsf{A}) = \{seeds\}$.
- *Conclusion:* $\mu(\mathsf{C}) = \{seeds\}$.

We can evaluate what happens when we take the context $\Delta' = \{dietary\_contributions\}$*, due to* $\mu(\mathsf{A}) = \{vegetal\_fats, proteins, antioxidants, minerals\}$ *and* $\mu(\mathsf{C}) = \{calcium, antioxidants, proteins, fatty\_acids\}$.

In addition to particularize the analogy between arguments, the context-aware scheme presented is useful to give a new meaning to relations between arguments when they are considered abstract entities without internal structure, which will be addressed in future work.

5 Related Works and Conclusions

Few studies exist formalizing the argumentation schemes proposed by Walton. Amgoud [1] put forward that argumentation from analogies has not been exploited profitably by AI, being the structure-mapping model [4] the exception. Nevertheless, any attempt to deal with the use of analogies in the argumentative process should include three aspects: the difference of an argumentative process from analogies with the argumentative process in general, the definition of attacks and the evaluation of arguments in this new approach. Prakken [24] proposed Argumentation Systems with Structured Arguments, which used the structure of arguments and external preference information to define the a defeat relation. Regarding argumentation schemes, Prakken [25] proposes that modeling reasoning using argumentation schemes necessarily involves

developing a method combining issues of non-monotonic logic and dialogue systems.Regarding to preference relation between arguments, Cecchi *et al.* [10] 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. Specifically, with regards to formalizing argumentation schemes, Hunter [16] 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 introducing them.

We have presented a formalism based on the comparison of arguments through descriptors. A descriptor is a word or a label that describes an aspect or element that the argument refers to. The arguments can be compared if they share a set of descriptors that represent the context of comparison. In order to compare the arguments, we have defined an analogy relation that considers the similarities and differences between arguments under certain context. We have formulated a Context-Aware Scheme based on Scheme from Analogy proposed by Walton [31, 29]. The goal of this formalization is to make it more useful to use reasoning patterns based on similarities and difference arguments in the field of AI. Different instruments can be specified to establish the comparison of the arguments, for example, the descriptors. Regardless of the type of instrument used, comparisons adjusted to a particular context allow us to add common sense to the reasoning of the agent. Among the main future work to address we can mention the specification of the maapping function between arguments and the definition of a framework that makes this type of schemes more useful for AI.

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