SEMANTIC ARGUMENTATION
IN DYNAMIC ENVIRONMENTS

Jörn Sprado and Björn Gottfried
Centre for Computing Technologies, University of Bremen, Germany

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Abstract: Decision Support Systems play a crucial role when controversial points of views are to be considered in order to make decisions. In this paper we outline a framework for argumentation and decision support. This framework defines arguments which refer to conceptual descriptions of the given state of affairs. Based on their meaning and based on preferences that adopt specific viewpoints, it is possible to determine consistent positions depending on these viewpoints. We investigate our approach by examining soccer games, since many observed spatiotemporal behaviours in soccer can be interpreted differently. Hence, the soccer domain is particularly suitable for investigating spatiotemporal decision support systems.

1 INTRODUCTION

Over the last years there has been an increasing interest in the fields of Decision Support Systems and Artificial Intelligence (AI) to investigate argumentation approaches. As a promising model for reasoning about inconsistent knowledge (Amgoud et al., 2008; Bench-Capon and Dunne, 2007) we investigate argumentation frameworks to examine the behaviours of objects, i.e. we are looking for how to provide decision support in the context of spatiotemporal systems. That is an example in the soccer domain looks like this: from one point of view the behaviours of soccer player might be inconsistent since not all behaviours support a given strategy; however, another point of view might argue for another strategy for which the behaviours are consistent; and yet another view would state that the players were not able to get to a common strategy – it is then the decision of the coach which player to censure in which way and with which kinds of arguments. Argumentation frameworks allow specific conclusions to be derived about what is true or rather forms a consistent argumentation. In our case in order to evaluate spatiotemporal group interactions.

1.1 Motivation

Fig. 1 shows the 73rd minute of the game Costa Rica–Germany of the world championship 2006: players of the black team (Costa Rica) attack the white team (Germany); player no. 9 tries to run towards the front middle in order to receive the ball the attacker is going to pass through the German players. The motion pattern among the teammates of Costa Rica is a pattern in which all players move towards the goal. Wanchope (no. 9) runs into the penalty area, preparing for getting the pass from no. 10. The pattern among the German players shows the tendency of two of the teammates to meet in order to avoid a gap and to get the ball. That is Metzelder (no. 21) and Mertesacker (no. 17) move towards the attacker while Friedrich (no. 3) moves towards the middle expecting the ball in the middle, trying to beat Wanchope. Comparing these two patterns within the teams it clearly shows that the strategy of

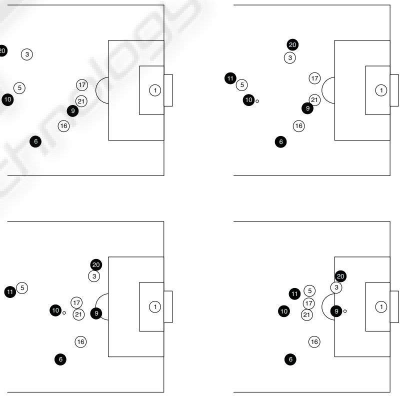

Figure 1: Four following scenes of the 73rd minute of the game Costa Rica–Germany of the world championship 2006

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the Costa Rica teammates follow one strategy, while the German defenders follow simultaneously two different strategies: no. 21 and no. 17 fight the attacker, while no. 3 prepares for dealing with no. 20 of the other team. The decision of no. 3 to keep in touch with his opposing player spoils a common strategy of the German team which could be an offside trap.

The described scene illustrates a complex situation where different objects interact in a dynamic environment. To argue in such a complex situation we have to consider all those interactions.

1.2 Overview

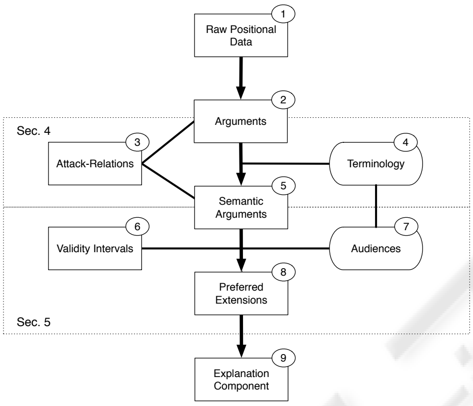

Figure 2: Argumentation generation as a process.

A typical argumentation generation process is shown in Fig. 2. Input of the whole process are raw positional data and the output is an explanation component for the input data. The input data represents at the most basic level spatiotemporal object interactions. Conversely, an explanation of such object interactions is provided by the explanation component. An explanation describes at an abstract semantic level what is going on, while the raw positional input data are only positional measurements. A generated explanation might in particular be useful for making decisions. The complexity of such a process is due to the goal of bridging the gap between pure measurements and meaningful explanations of those measurements. For this purpose basically two methods are employed:

- *argumentation frameworks* are used in order to describe which concepts form consistent scenarios, and conversely, which concepts cannot be reconciled (Dung, 1995);
- the terminology of both a specific domain and of argumentation frameworks is defined by methods of *description logics* (Baader et al., 2003).

The process of explanation generation, and hence decision support, is thus, a process of looking for consistent sets of arguments. Domain specific arguments are defined by an ontology, and the more abstract level of argumentation frameworks is itself described by another ontology. Before interpreting data, a priori knowledge is modelled by means of these ontologies. The process is as follows; taking the raw positional data (Box 1), arguments about basic spatiotemporal behaviour patterns are constructed (Box 2). Then attack-relations among arguments are constructed (Box 3) that define which arguments attack other arguments. Referring to terminological knowledge (Box 4) which is defined a priory, semantic arguments (Box 5) are constructed; they describe at the semantic level how concepts characterise the data. Which arguments temporally relate are described by validity intervals (Box 6): arguments might relate because they follow each other and can therefore influence each other; or they can temporally coincide, or they can at least temporally overlap. Audiences (Box 7) determine specific viewpoints which can be taken in order to justify a specific argumentation. Audiences influence which of the currently instantiated arguments do form consistent sets of arguments with respect to these audiences, that is preferences are made (Box 8). Preferences and audiences, determine eventually which spatiotemporal behaviours stand for which arguments, and hence decisions, when taking a specific point of view.

While in (Sprado and Gottfried, 2008b) the analysis of raw positional data is investigated and while in (Sprado and Gottfried, 2008a) the argument construction process is investigated, this paper focuses on the argumentation process itself at the semantic level. The explanation component is not further dealt with here, but the computation results of preferred extensions provide the core knowledge which is necessary in order to develop explanation components.

After having revisited description logics (Sec. 2) and argumentation frameworks (Sec. 3), in Sec. 4 we propose our approach how to describe arguments semantically by a given set of arguments and attack-relations. Then in Sec. 5.1 audiences are introduced on which consistent positions can be found (Sec. 5.2). Finally, Sec. 6 concludes with a discussion.

2 ONTOLOGIES AND DESCRIPTION LOGICS

A popular definition of ontologies in AI is proposed by Gruber:

> an ontology is an explicit formal specification
> of a shared conceptualisation (Gruber, 1995).

Such a conceptualisation corresponds to a way of thinking about some domain (Uschold, 1998). Following the W3C Web Ontology language (Patel-Schneider et al., 2004) the ontologies shown in this paper are expressed by using a description logic (DL). Description logics are part of the family of knowledge representation languages that are subsets of first-order logic (cf. (Sattler et al., 2003)). A description logic is a concept-based knowledge representation formalism with well-defined model-theoretic semantics (Baader et al., 2003). A DL consists of atomic concepts (unary predicates), atomic roles (binary predicates), and individuals (constants). The expressive power of DL languages is restricted to a small set of constructors for building complex concepts and roles. Implicit knowledge about concepts and individuals can be inferred automatically through using inference procedures. For precise formal semantics of DLs see (Baader et al., 2003).

A description logic knowledge base is naturally separated into two parts: a TBox containing intensional knowledge that describes general properties of concepts and an ABox containing extensional knowledge that is specific to the individuals of the universe of discourse.

3 ARGUMENTATION FRAMEWORKS

In this paper we use argumentation frameworks in order to construct and compare arguments. An abstract argumentation framework is proposed by Dung (Dung, 1995). We stick accordingly to his formalisation:

Definition 1 (**Argumentation Framework).** *An argumentation framework (AF) is a pair* $AF = (\mathcal{AR}, attack)$*, where* $\mathcal{AR}$ *is a set of arguments and* $attack \subseteq \mathcal{AR} \times \mathcal{AR}$ *is an attack-relation.*

The relation $attack(x,y)$ expresses that an argument x attacks another argument y. The acceptability of arguments can be defined based on the notions of defence and conflict-freeness.

Definition 2 (**Conflict-freeness).** *Let* $\mathcal{S} \subseteq \mathcal{AR}$ *be a set of arguments in an argumentation framework* AF*. A set of arguments* $\mathcal{S}$ *is conflict-free iff there are no arguments* $x,y \in \mathcal{S}$ *with* $\exists x \exists y\ attack(x,y)$*.*

Definition 3 (**Defence).** *A set of arguments* $\mathcal{S}$ *defends an argument* $x \in \mathcal{AR}$*, that is to say* x *is acceptable with respect to* $\mathcal{S}$ *denoted as* $acceptable(x,y)$*, iff* $\forall y \in \mathcal{AR}\ \exists z \in \mathcal{S}\ attack(y,x) \rightarrow attack(z,y)$*.*

Acceptability semantics have also been introduced in Dung's abstract argumentation framework. In order to find consistent positions within an AF (cf. Sec. 1) preferred extensions are of interest.

Definition 4 (**Preferred Extension).** *A conflict-free set of arguments* $\mathcal{S}$ *is admissible if* $\forall x\ acceptable(x,S)$ *with* $x \in \mathcal{S}$*. A conflict-free and admissible set of arguments* $\mathcal{S}$ *is a preferred extension iff it is a maximal (with respect to set inclusion) admissible subset of* $\mathcal{AR}$*.*

Furthermore, a value-based argumentation system is defined by Bench-Capon (Bench-Capon, 2003) as follows:

Definition 5 (**Value-based AF).** A value-based argumentation framework (VAF) is a triple $VAF = (\mathcal{H}(\mathcal{AR}, attack)), \mathcal{V}, \eta)$, where $(\mathcal{AR}, attack)$ is an argumentation framework, $\mathcal{V}$ is a non-empty set of values and $\eta : \mathcal{AR} \rightarrow \mathcal{V}$ is a function that associates each argument $x \in \mathcal{AR}$ with a value $\eta(x) \in \mathcal{V}$.

The set of values $\mathcal{V}$ within the VAF represents types of arguments. Based on these values different audiences enable the consideration of diverse positions.

Definition 6 (**Audience).** *Let* $\mathcal{AR}$ *be a set of arguments. An audience for a* $\mathcal{VAF}$ *is a binary relation* $\mathcal{R} \subset \mathcal{AR} \times \mathcal{AR}$ *whose (irreflexive) transitive closure* $\mathcal{R}^*$ *is asymmetric.*

Definition 7 (**Acceptability Semantics).**
Let $(\mathcal{H}(\mathcal{AR}, attack)), \mathcal{V}, \eta)$ *be a VAF and* $\mathcal{R}$ *an audience.*

1. *A set of arguments* $\mathcal{S}$ *is conflict-free with respect to an audience* $\mathcal{R}$ *iff there are no arguments* $x,y \in \mathcal{S}$ *with* $\exists x \exists y\ attacks_{\mathcal{R}}(x,y)$*.*
2. *An argument* x *is acceptable with respect to a set of arguments* $\mathcal{S}$ *and an audience* $\mathcal{R}$ *denoted as* $acceptable_{\mathcal{R}}(x,\mathcal{S})$ *iff* $\forall y \exists z\ attacks_{\mathcal{R}}(y,x) \rightarrow attacks_{\mathcal{R}}(z,y)$ *with* $x,y \in \mathcal{AR}$ *and* $z \in \mathcal{S}$*.*
3. *A conflict-free set of arguments* $\mathcal{S}$ *is admissible with respect to an audience* $\mathcal{R}$ *denoted as* $admissible_{\mathcal{R}}(\mathcal{S})$ *iff* $\forall x\ acceptable_{\mathcal{R}}(x,\mathcal{S})$ *with* $x \in \mathcal{S}$*.*
4. *A set of arguments* $\mathcal{S}$ *is a preferred extension for an audience* $\mathcal{R}$ *iff it is a maximal (with respect to set inclusion) admissible subset of* $\mathcal{AR}$ *with respect to an audience* $\mathcal{R}$*.*

4 SEMANTIC DESCRIPTION OF ARGUMENTS

Arguments and their attack-relations have been obtained by analysing raw positional data before de-

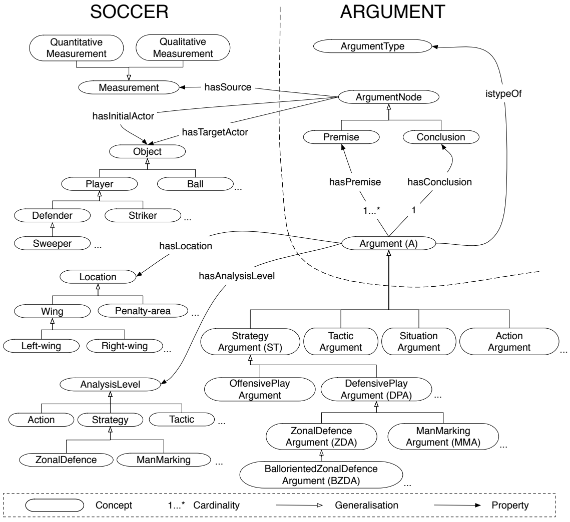

Figure 3: Concepts and relations of the soccer and arguments domain ontology. For simplicity, only some of the concepts and relations are shown.

scribing the meaning of arguments (cf. Fig. 2). Table 1 presents some informal arguments for the scenes shown in Fig. 1. For instance, argument *A* means that player no. 20 of the black team is marked by no. 3 of the white team. Argument *B* says that two players of the white team attack no. 10 of the black team. Moreover, arguments *C* and *D* state different moving directions of pairs of objects. Argument *E* points out an offside-trap of the white team which is in conflict with the arguments *C*, *D* and *F*. Eventually, arguments *F* and *G* denote different strategies of the white team; a *man-to-man marking* strategy is completely different to a *zonal defence* strategy. Further conflicts can be found among these arguments. Additionally, there are different kinds of arguments, e.g. two objects are involved in argument *A* which says something about an action between players, while argument *F* makes a statement about a team strategy.

The idea of a semantic description of arguments is to represent their meaning explicitly and thus, to exploit machine-processable metadata to arguments. For this purpose we use ontologies which already have been widely discussed in the Semantic Web area. Arguments with clear semantics become machine-interpretable and further inference mechanisms can be applied (cf. large-scale argumentation (Rahwan, 2008; Rahwan and Banihashemi, 2008)).

In order to establish the link between the informal description of an argument and its ontological description we follow the idea of registration mappings (Bowers et al., 2004) to have separate descriptions of structural details and semantics. This has the advantage that the semantics of an argument can be specified more accurately because the specification does not try to mirror the structure of the arguments.

Table 1: Example arguments and attack-relations.

Id	Meaning	$\mathcal{A}$
A	man-marking of black no. 20 by white no. 3	B, E, G
B	double-teaming of black no. 10 by white no. 17 and no. 21	A, F
C	different moving direction of white no. 3 and no. 17	E, G
D	different moving direction of white no. 3 and no. 21	E, G
E	offside-trap of team white	A, C, D
F	man-to-man marking of team white	B,G
G	zonal defence of team white	A, C, D, F

5 CONCEPT-BASED ARGUMENTATION

Our running example involves multiple arguments for and against different claims. In this section we show exemplarily how to reconcile these conflicts and how to form consistent sets of arguments using our new approach on *concept-based argumentation*.

Preferred extensions are of main interest because they enable to form consistent sets of arguments. While we look at preference-based argumentations in dynamic scenes we focus on obtaining preferred extensions which hold with respect to an audience for an observed time interval. We know that every argumentation framework has at least one preferred extension which might be the empty set (Dung, 1995). Therefore, the empty set would be a solution in general. But we are interested in finding out whether there are other admissible sets of arguments.

We define concept-based argumentation frameworks in the following way:

Definition 8 (**Abstract Concept-based AF).** *A DL knowledge base* $\mathcal{K} = (\mathcal{T}, \mathcal{A})$ *represents the domain of interest, where* $\mathcal{T}$ *is a TBox and* $\mathcal{A}$ *is a ABox. A concept-based argumentation framework is a triple*

$$CAF = (\mathcal{H}(\mathcal{AR}, attack), \mathcal{A}, \nu),$$

where $\mathcal{H}$ *is an argumentation framework and* $\nu : \mathcal{AR} \rightarrow \mathcal{A}$ *is a mapping that assigns ABox assertions to each argument* $y \in \mathcal{AR}$*, denoted as* $x = \nu(y)$.

The concept-based argumentation framework is a specialisation of a VAF which associates concepts instead of simple values with arguments. That is to determine the acceptability of arguments we can refer to VAFs (Bench-Capon, 2003). However, a main difference is that semantic arguments are mapped to concepts automatically as a result of inference procedures. For instance, if we change the semantic description of an argument, an appropriate mapping within the argumentation system will be automatically adjusted. Thus, argumentation becomes more flexible and more scalable.

5.1 Concept-based Audiences

According to VAFs (Bench-Capon, 2003) a concept-based argumentation framework also provides mechanisms for considering diverse positions in one argumentation system. We use audiences in order to determine multiple preferred extensions for different viewpoints.

Definition 9 (Concept-based Audience). *Let* $\mathcal{K} = (\mathcal{T}, \mathcal{A})$ *be a DL knowledge base,* $\mathcal{C}$ *be a set of concepts of* $\mathcal{T}$ *and* $CAF = (\mathcal{H}(\mathcal{AR}, attack), \mathcal{A}, \nu)$ *be an abstract concept-based argumentation framework. An audience* $\mathcal{I}$ *for a* $\mathcal{CAF}$ *is a binary relation* $\mathcal{I} \subset \mathcal{C} \times \mathcal{C}$ *whose taxonomic expansion is asymmetric. An argument* a_m *is preferred to* a_n *in the audience* $\mathcal{I}$ *denoted* ($a_m \succ a_n$) *if* $(a_m, a_n) \in \mathcal{I}_{\mathcal{T}}$.

In contrast to Bench-Capon, we allow preferences among arguments to be described with concepts instead of simple values. We can define preferences on any sub-concepts of an Argument. If we like to prefer arguments (cf. Fig. 3) of type ZDA (ZonalDefenceArgument) to those of MMA (ManMarkingArgument) this can be denoted as ZDA $\succ$ MMA.

As we state preferences on concepts we have to consider that preferences are also propagated to all sub-concepts which will be ensured by a taxonomic expansion. This means that knowledge in terms of *concept A subsumes concept B* will be directly represented within an audience. Consequently, a taxonomic expansion extends an audience with concepts of the subsumption hierarchy.

Definition 10 (Taxonomic Expansion). *Let* $\mathcal{K} = (\mathcal{T}, \mathcal{A})$ *be a DL knowledge base,* $\mathcal{C}$ *be a set of concepts of* $\mathcal{T}$ *and* $\mathcal{I}$ *an appropriate audience. An audience is a taxonomic expansion* $\mathcal{I}_{\mathcal{T}}$ *of an audience* $\mathcal{I}$ *with respect to a TBox* $\mathcal{T}$ *that satisfies the following constraints for all possible pairs* (C_n, C_m) *of* $\mathcal{C}$*:*
If $(C_n, C_m) \in \mathcal{I}$ *then* $(C_n, C_m) \in \mathcal{I}_{\mathcal{T}}$ *and*

- *if there is a sub-concept* $C_{sub1} \sqsubseteq C_n$ *with respect to* $\mathcal{T}$ *for a pair* $(C_n, C_m) \in \mathcal{I}$ *then* $(C_{sub1}, C_m) \in \mathcal{I}_{\mathcal{T}}$,
- *if there is a sub-concept* $C_{sub2} \sqsubseteq C_m$ *with respect to* $\mathcal{T}$ *for a pair* $(C_n, C_m) \in \mathcal{I}$ *then* $(C_n, C_{sub2}) \in \mathcal{I}_{\mathcal{T}}$,
- *and if there are sub-concepts* C_{sub1}, C_{sub2} *with* $C_{sub1} \sqsubseteq C_n$ *and* $C_{sub2} \sqsubseteq C_m$ *with respect to* $\mathcal{T}$ *for a pair* $(C_n, C_m) \in \mathcal{I}$ *then* $(C_{sub1}, C_{sub2}) \in \mathcal{I}$.

In case of $(C_n, C_m) \notin \mathcal{I}$ *and* $C_n \sqsubseteq C_m$ *wrt* $\mathcal{T}$*:*

1. *if we mainly prefer more general concepts then* $(C_m, C_n) \in \mathcal{I}_{\mathcal{T}}$. *Such a taxonomic expansion will be denoted as* $\mathcal{I}_{\mathcal{T}>}$.
2. *otherwise if we mainly prefer more specific ones then* $(C_n, C_m) \in \mathcal{I}_{\mathcal{T}}$. *Such a taxonomic expansion will be denoted as* $\mathcal{I}_{\mathcal{T}<}$.

Bench-Capon already mentioned for value-based argumentation frameworks that an audience $\mathcal{I}$ typically does not describe a unique total ordering of the values; there are in fact multiple compatible orderings. They are referred to as specific audiences compatible with $\mathcal{I}$ (Bench-Capon et al., 2007). This also holds for concept-based audiences.

Definition 11 (Specific Audience). *Let* $\mathcal{K} = (\mathcal{T}, \mathcal{A})$ *be a DL knowledge base,* $\mathcal{C}$ *be a set of concepts and* $\mathcal{I}$ *an audience. A specific audience* α *is a total ordering of* $\mathcal{C}$ *with respect to an audience* $\mathcal{I}$ *and*

$$\forall C_1, C_2 \in \mathcal{C} : \langle C_1, C_2 \rangle \in \alpha \implies \langle C_2, C_1 \rangle \notin \mathcal{I}_{\mathcal{T}}$$

In relation to Bench-Capon we denote a set of specific audiences with $\chi(\mathcal{I})$.

Example 1. *Let A, B, C, D and E be concepts and* $B \sqsubseteq A, C \sqsubseteq A, D \sqsubseteq B, E \sqsubseteq C$ *are terminological axioms with respect to a TBox* $\mathcal{T}$ *of a DL knowledge base.*

1. *If* $\mathcal{I} = \emptyset$ *an audience then*

$$\mathcal{I}_{\mathcal{T}_<} = \{\langle B,A\rangle, \langle C,A\rangle, \langle D,B\rangle, \langle E,C\rangle\} \text{ and}$$

$$\chi(\mathcal{I}_{\mathcal{T}_<}) = \left\{ \begin{array}{c} \{\langle D,B,E,C,A\rangle\}; \{\langle E,C,D,B,A\rangle\} \\ \{\langle D,E,C,B,A\rangle\}; \{\langle D,E,B,C,A\rangle\} \\ \{\langle E,D,C,B,A\rangle\}; \{\langle E,D,B,C,A\rangle\} \end{array} \right\}$$

corresponds to the orderings $D \succ B \succ E \succ C \succ A$, $E \succ C \succ D \succ B \succ A$, $D \succ E \succ C \succ B \succ A$, $D \succ E \succ B \succ C \succ A$, $E \succ D \succ C \succ B \succ A$ *and* $E \succ D \succ B \succ C \succ A$.

2. *If* $\mathcal{I} = \{\langle B,C\rangle\}$ *an audience then*

$$\mathcal{I}_{\mathcal{T}_<} = \{\langle B,C\rangle, \langle B,A\rangle, \langle C,A\rangle, \langle D,B\rangle, \langle E,C\rangle, \langle B,E\rangle, \langle D,C\rangle, \langle D,E\rangle\} \text{ and}$$

$$\chi(\mathcal{I}_{\mathcal{T}_<}) = \{\langle B,C\rangle, \langle B,A\rangle, \langle C,A\rangle, \langle D,B\rangle, \langle E,C\rangle, \langle B,E\rangle, \langle D,C\rangle, \langle D,E\rangle\}$$

so that $\chi(\mathcal{I}_{\mathcal{T}_<}) = \{\mathcal{I}_{\mathcal{T}_<}\}$, *i.e.* $\chi(\mathcal{I}_{\mathcal{T}_<})$ *contains exactly one specific audience which corresponds to the ordering* $D \succ B \succ E \succ C \succ A$.

5.2 Determining Consistent Positions

We employ semantic information of arguments as introduced in Sec. 4 and look for answers of concrete questions, as: does the German team follow one strategy (e.g. to apply an offside trap - cf. Sec. 1.1)?

To use the underlying semantics we determine the formal structure of the arguments and apply subsumption reasoning to the argument descriptions (introduced in Sec. 4). For this purpose we use a standard DL reasoner (Sirin et al., 2007). As a result we get sub-concepts of the top-level concept Argument (cf. Fig. 3). Fig. 4 shows arguments and inferred concept affiliations as well as their defeat relations with reference to a specific concept-based audience (for simplicity, we have only considered a selection of concepts of our terminology). For arguments shown in Fig. 4 and a specific audience $\mathsf{BZDA} \succ \mathsf{ZDA} \succ \mathsf{MMA} \succ \mathsf{SMA} \succ \mathsf{DPA} \succ \mathsf{ST} \succ \mathsf{A}$ (which is compatible to the audience $\mathcal{I} = \langle ZDA, MMA \rangle$), a set of arguments $\mathcal{S} = \{B, E, G\}$ is obtained as a preferred extension. However, there does not exist any preferred extension which contains the arguments *A* and *B*; hence, claims about a common strategy among the German teammates cannot be supported.

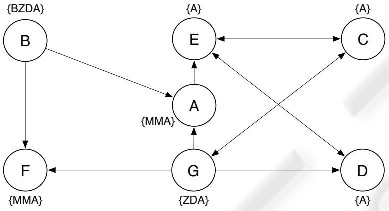

Figure 4: Arguments (with inferred concept affiliations) and successful attacks corresponding to a total ordering $\mathsf{BZDA} \succ \mathsf{ZDA} \succ \mathsf{MMA} \succ \mathsf{DPA} \succ \mathsf{ST} \succ \mathsf{A}$ of an audience $\mathcal{I} = \langle ZDA, MMA \rangle$ (see Fig. 3 for abbreviations).

6 CONCLUSIONS

We have presented an approach basically based on two paradigms: that of argumentation frameworks and that of description logics. The former is employed for analysing consistent sets of arguments, given a set of instantiated arguments at some given time. The latter is primarily used for defining terminological knowledge in order to characterise arguments at the semantic level; that is to say that instead of value-based systems, concept-based arguments are introduced. Concept-based argumentations are more flexible in those appropriate mappings within an argumentation system can be automatically adjusted if we would change the semantic description of arguments. Moreover, we can define preferences among arguments at the conceptual level instead of taking simple values, as is the case in value-based argumentation frameworks.

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