Dialogue Games in Defeasible Logic

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Abstract. In this paper we show how to capture dialogue games in Defeasible Logic. We argue that Defeasible Logic is a natural candidate and general representation formalism to capture dialogue games even with requirements more complex than existing formalisms for this kind of games. We parse the dialogue into defeasible rules with time of the dialogue as time of the rule. As the dialogue evolves we allow an agent to upgrade the strength of unchallenged rules. The proof procedures of [1] are used to determine the winner of a dialogue game.

1 Introduction

Agents interact with other agents. The nature of the interactions between two agents can be of various kinds. Here we consider two types of interaction: cooperative and adversarial. In a cooperative situation the agents exchange information with the aim of reaching a common goal, while in an adversarial scenario the goals of the parties are conflicting. However, this does not imply a clear-cut dissimilarity between the two types of interaction. Conflicting sub-goals often are found amongst agents in a cooperative setting, while all the same in an adversarial discussion one agent may partially accept a proposal of her adversary as it provides for a stronger justification of her case.

These kinds of interactions are part of the broader field of argumentation, and formal argumentation is the branch using logic and (formal methods in general) to model it. Over the past few years a line of research emerged for the representation of these type of arguments: dialogue games. Dialogue games are proven extremely useful for modelling some forms of legal reasoning. In this paper we focus on one form of dialogue games, the adversarial, where the two parties debate over one topic.

Most formal models of dialogues provide computational and procedural representations of some real-life domain (e.g., legal reasoning). Dialogue games are by their own nature defeasible, it means that arguments put forward by one of the agents in support of a conclusion can be defeated by contrary evidence put forward by the other agent. Accordingly, standard model-theoretic semantics is not appropriate for this kind of reasoning. Dung [4] proposed argumentation semantics to obviate this issue. The main idea of argumentation semantics is that the main objects we evaluate are “arguments”[4].

[4] In the abstract formulation of the argumentation semantics ‘arguments’ is left unspecified, however, in the majority of concrete instances of the argumentation framework, arguments

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Various relationships (e.g. attack, rebut and defeat) between arguments are defined by the semantics, and the relationships are extended to sets of arguments. The key notion for a set of arguments is the notion of *support*, that is whether a set of arguments is self-consistent and provides the base to derive a conclusion. In other words, if it is possible to prove the conclusion from the rules, facts and assumptions in the set of supporting arguments. A conclusion is justified, and thus provable, if there is a set of supporting arguments and all counterarguments are deficient when we consider the arguments in the set of supporting arguments. Various argumentation semantics have been proposed to capture different relationships between supporting and opposing set of arguments. However, in general some forms of argumentation semantics are able to characterise dialogue games [18].

Defeasible Logic [13,1] is an efficient non-monotonic formalism that encompasses many logics proposed for legal reasoning. Defeasible Logic can be characterised in terms of argumentation semantics [5], thus the correspondence between Defeasible Logic on one side and dialogue games on the other follows implicitly from their common semantics. The aim of this paper is to propose a direct mapping between dialogue games and Defeasible Logic, and to show that Defeasible Logic offers a general, powerful and computationally efficient framework to model and to extend dialogue games.

The paper is organised as follows: in Section 2 we outline the basic ideas of dialogue games, then Section 3 provides an informal introduction to defeasible logic, and in Section 4 we show how to adapt Defeasible Logic to model dialogue games. We conclude the paper in Sections 5 and 6 with a discussion of related work and possible research extensions.

2 On dialogue games

We consider dialogue games as a game where we have two players called the *Proponent* and the *Opponent*. Each player is equipped with a set of arguments, a subset of which the players *move*, i.e., take turns in putting forward. The aim of the game is to justify a particular conclusion while adhering to the particular protocol scheme governing the game. A basic protocol for the admissible moves by the players be, for the proponent, that the current move attacks the previous move of the opponent, and that the main claim (the content of the dispute) follows from the arguments assessed as currently valid. For the opponent we have that the arguments of the move attack the previous move, and the main claim is not derivable. Even though more complex winning conditions are possible, by a basic protocol a player wins the dialogue game when the other party is out of admissible moves.

3 Basic Defeasible Logic

Over the years Defeasible Logic [13,1] proved to be a simple, flexible, rule based non-monotonic formalism able to capture different and sometimes incompatible facets of

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are defined as a chain of reasoning based on facts or assumptions and rules captured in some formal language or logic.

non-monotonic reasoning [2], and efficient and powerful implementations have been proposed [12,8].

Knowledge in Defeasible Logic can be represented in two ways: facts and rules.

Facts are indisputable statements represented by ground literals. For example, "Tweety is a penguin" is represented by $Penguin(Tweety)$.

A *rule*, on the other hand, describes the relationship between a set of literals (premises) and a literal (conclusion), and we can specify how strong the relationship is. As usual rules allow us to derive new conclusions given a set of premises. We distinguish between *strict rules*, *defeasible rules* and *defeaters* represented, respectively, by expressions of the form $A_1,\ldots,A_n \rightarrow B$, $A_1,\ldots,A_n \Rightarrow B$ and $A_1,\ldots,A_n \leadsto B$, where $A_1,\ldots,A_n$ is a possibly empty set of prerequisites (causes) and B is the conclusion (effect) of the rule. We only consider rules that are essentially propositional, this means that rules containing free variables are to be interpreted as rule schemas and the correspond to the set of their ground instances.

Strict rules are rules in the classical sense: whenever the premises are indisputable then so is the conclusion. Thus they can be used for definitional clauses. An example of a strict rule is "Penguins are birds", formally: $Penguin(X) \rightarrow Bird(X)$.

Defeasible rules are rules that can be defeated by contrary evidence. An example of such a rule is "Birds usually fly": $Bird(X) \Rightarrow Fly(X)$. The idea is that if we know that X is a bird, then we may conclude that X can fly *unless there is other evidence suggesting that she may not fly*.

Defeaters are special kind of rules. They are used to prevent conclusions, not to support them. For example: $Heavy(X) \leadsto \neg Fly(X)$. This rule states that if something is heavy then it might not fly. This rule can prevent the derivation of a "fly" conclusion. On the other hand it cannot be used to support a "not fly" conclusion.

Defeasible logic (DL) is a "skeptical" non-monotonic logic, meaning that it does not support contradictory conclusions. Instead DL seeks to resolve conflicts. In cases where there is some support for concluding A but also support for concluding $\neg A$, DL does not conclude either of them (thus the name "skeptical"). If the support for A has priority over the support for $\neg A$ then A is concluded. No conclusion can be drawn from conflicting rules in DL unless these rules are prioritised. The *superiority relation* among rules is used to define priorities among rules, that is, where one rule may override the conclusion of another rule. For example, given the defeasible rules

$$r : Bird(X) \Rightarrow Fly(X) \qquad r' : Penguin(X) \Rightarrow \neg Fly(X)$$

which contradict one another, no conclusive decision can be made about whether a Tweety can fly or not. But if we introduce a superiority relation $\succ$ with $r' \succ r$, then we can indeed conclude that Tweety cannot fly since it is a penguin.

We now give a short informal presentation of how conclusions are drawn in DL. A D be a theory in DL (i.e., a collection of facts, rules and a superiority relation). A *conclusion* of D is a tagged literal and can have one of the following four forms:

$+\Delta q$ meaning that q is definitely provable in D (i.e., using only facts and strict rules).
$-\Delta q$ meaning that we have proved that q is not definitely provable in D.
$+\partial q$ meaning that q is defeasibly provable in D.
$-\partial q$ meaning that we have proved that q is not defeasibly provable in D.

Strict derivations are obtained by forward chaining of strict rules, while a defeasible conclusion p can be derived if there is a rule whose conclusion is p, whose prerequisites (antecedent) have either already been proven or given in the case at hand (*i.e.*, facts), and any stronger rule whose conclusion is $\neg p$ has prerequisites that fail to be derived. In other words, a conclusion p is derivable when:

- p is a fact; or
- there is an applicable strict or defeasible rule for p, and either
  - all the rules for $\neg p$ are discarded (i.e., are proved to be not applicable) or
  - every applicable rule for $\neg p$ is weaker than an applicable strict[5] or defeasible rule for p.

Formally a Defeasible Logic theory (as formalised in [3]) is a structure $D = (F, R, >)$ where F is a finite set of factual premises, R a finite set of rules, and $>$ a superiority relation on R. Given a set R of rules, we denote the set of all strict rules in R by R_s, the set of strict and defeasible rules in R by R_{sd}, the set of defeasible rules in R by R_d, and the set of defeaters in R by R_{dft}. $R[q]$ denotes the set of rules in R with consequent q. In the following $\sim p$ denotes the complement of p, that is, $\sim p$ is $\neg q$ if $p = q$, and $\sim p$ is q if p is $\neg q$. For a rule r we will use $A(r)$ to indicate the body or antecedent of the rule and $C(r)$ for the head or consequent of the rule. A rule r consists of its antecedent $A(r)$ (written on the left; $A(r)$ may be omitted if it is the empty set) which is a finite set of literals, an arrow, and its consequent $C(r)$ which is a literal. In writing rules we omit set notation for antecedents.

Provability is based on the concept of a derivation (or proof) in D. A derivation is a finite sequence $P = (P(1), \dots, P(n))$ of tagged literals. Each tagged literal satisfies some proof conditions. A proof condition corresponds to the inference rules corresponding to one of the four kinds of conclusions we have mentioned above. $P(1..i)$ denotes the initial part of the sequence P of length i. Here we state the conditions for strictly and defeasibly derivable conclusions (see [1] for the full presentation of the logic):

If $P(i+1) = +\Delta q$ then
  (1) $q \in F$, or
  (2) $r \in R_s[q], \forall a \in A(r) : +\Delta a \in P(1..i)$.

If $P(i+1) = +\partial q$ then
  (1) $+\Delta q \in P(1..i)$, or
  (2) (2.1) $\exists r \in R_{sd}[q] \forall a \in A(r) : +\partial a \in P(1..i)$ and
    (2.2) $-\Delta \sim q \in P(1..i)$ and
    (2.3) $\forall s \in R[\sim q]$ either
      (2.3.1) $\exists a \in A(s) : -\partial a \in P(1..i)$ or
      (2.3.2) $\exists t \in R_{sd}[q]\ \forall a \in A(t) : +\partial a \in P(1..i)$ and $t > s$.

4 Modelling dialogue games in Defeasible Logic

During the dialogue game the agents take turns in presenting their arguments (rules). The literal the agents are trying to prove or disprove will be called the critical literal.

[5] Note that a strict rule can be defeated only when its antecedent is defeasibly provable.

Each agent has knowledge that initially is known only to the agent (private knowledge). Initially all the arguments are private. In addition, both agents have access to a set of common knowledge. By putting forward arguments from the private knowledge of an agent, these arguments becomes part of the set of common knowledge. We assume that all arguments (rules) are defeasible, acknowledging an agent's right to put forward interpretations of assumptions, fact and evidence in the way most favourable for his case (cf. [9]). The set of common arguments is continuously updated at each step and defeated defeasible rules are removed at each step. At any time the set of common arguments contains defeasible rules only from the current step t_i and adjacent previous step t_{i-1} and facts, strict rules from previous steps. The theory of common set of arguments is $T_{common} = (F, R, >)$, where F is the set of facts, R is the set of rules, $>$ is superiority relationship among the rules. At each step the proof procedure is applied on the critical literal. The nature of the game determines the burden as well as the winner of the game. A party wins the game if the proof is $+\Delta A$ (A is the critical literal) at any stage of the game. If a party at any stage of the game proves $+\partial A$ (A is the critical literal) the other party has the burden to produce proof of $-\partial A$, or $+\Delta\neg A$ or $+\partial\neg A$. Our notion of burden is restricted only to the critical literal unlike the notion of burden in [15].

The condition that a agent cannot repeat its rule is unnecessary in our model. If a rule r has been put forward and successfully defeated any counterarguments supporting the opposite conclusion $\neg C(s)$ the rule r is added to the common set of knowledge. In accordance to our protocol the rule r will effectively prevent the opponent from putting forward the defeated arguments (rules) for $\neg C(r)$ into the dialogue as we require all admissible arguments to be defeating opposing arguments presented at a previous step. In addition this criterion guarantees that the dialogue game terminates, since we assume the private and public set of arguments are finite.

4.1 A protocol

Mainly we adhere to the protocol of a dialogue game captured in [15,16,14,17]. Thus, the rules for our dialogue games are as follows:

1. The parties cannot present arguments in parallel. Thus, the parties take turn in presenting their arguments.
2. As we allow for each agent to put forward as argument the interpretations of rules and evidence in the way most favourable for his case, all arguments presented by an agent are initially treated as defeasible rules. If in next step the other party fails to provide valid counterarguments, these defeasible rules be upgraded to strict rules.
3. The arguments in support of a critical literal $\sim A$ presented by a party 1 at any step must attack (at least) the conclusion in support of the critical literal A put forward by the other party 2 in the previous step. Moreover, in order to prevent a strengthening of the defeasible rules in support of A in the set of common arguments and to remove from the set of common arguments all defeasible rules which has as conclusion A, party 1 must present at least one new argument with its own critical literal $\sim A$ as its conclusion.
4. An agent cannot attack its own arguments. In our dialogue game framework it is not admissible for an agent to contradict itself by putting forward rules with a conclusion that contradicts a rule previously presented by the agent.

5. A particular dialogue game is won by an agent when the other party at his turn cannot make an admissible move.
6. A argument r is stronger than an argument s, conflicting with r and played in the previous time-step, if r is not attacked in successive steps.

4.2 Strengthening of rules

Dialogues are parsed into defeasible theories. The time of a dialogue is translated as the time of a rule. All the rules presented at the current step t_i and at the adjacent previous step t_{i-1} are defeasible rules. Here we consider the time as a set of finite numbers and each number is one unit more or less than its previous or next number. If not immediately rebutted by the other party, we allow for the rule strength of a rule to be strengthened from defeasible into strict. A rule is represented as $R^t_x | x \in (d, s, sd)$ where t is the time (or the move when the rule has been played), d means the rule is defeasible, s means the rule is strict, sd means the rule is either strict or defeasible. We write $a@t$ to denote the literal a being put forward or upgraded at time t. The condition for upgrading a defeasible rule to a strict rule is described below.

If p is the conclusion of a defeasible rule of the adjacent previous step t_{i-1}, we upgrade the strength of the rule to strict in next step t_{i+1} if

$$\exists r \in R^{t'}_d[p], t' < t, \forall t'' : t' < t'' < t \; R^{t''}_{sd}[\sim p] = \emptyset \text{ and } \forall a \in A(r) : +\Delta a@t$$

We stipulate that strict rules are stronger than defeasible rules.

$$\forall t, \forall r \in R^t_s[q] \text{ and } \forall s \in R^t_d[\sim q],\; r >^t s$$

At each step of the game, if an argument (rule) has precedence over any contradictory defeasible rule of the previous steps, an agent is allowed to put forward that argument. The strength is determined either by previously known superiority relationships or the validity of the rule. We assume that if at time t_2 we have a *valid* rule $R^{t_2}_2$ which contradicts a defeasible rule $R^{t_1}_1$ of time t_1 and $t_2 > t_1$, the strength of $R^{t_2}_2$ is greater than $R^{t_1}_1$. We will use defeasible logic to determine strength of a new rule.

$$w >^t s \text{ iff } w > s \in (>) \text{ or } w \in R^{t'}[p],\; s \in R^t[\sim p] \text{ where } t' < t$$

4.3 Transition rules

The sets of common arguments construct the theories $T_1, T_2, T_3, \ldots$. Here the subscripts indicate the time when1 the sets of common arguments are constructed. At time 1, the game begins and arguments in support of a critical literal A are put forward by the proponent, then T_1 contains only defeasible rules. At time 2, the opponent proposes new defeasible rules which by the conditions presented in the Section 4.2 are stronger than some rules in theory T_1. The set of common arguments of the first two theories T_1 and T_2 consists only of defeasible rules. (Theory T_2 consists of defeasible rules from both time 1 and time 2.) Let the first theory $T_1 = (\{\}, R^1_d, >)$ be created from arguments (ARG_1) of the proponent, and the second theory $T_2 = (\{\}, R^2_d, >)$ be created through modifications of T_1 by arguments(ARG_2) from the opponent. Now the transition rules from first theory to second theory is

1. If $r \in R_d^1$ and $\forall s \in ARG_2$, $\neg C(s) \neq C(r) \wedge \neg C(s) \notin A(r)$, then $r \in R_d^2$.
2. All rules of ARG_2 are added to T_2 as defeasible rule. Here we assume that ARG_2 is valid and that a valid argument, by the above defined precedence relations, is stronger than any contradictory argument of the previous step.

At time n, $n > 2$ theory T_n is created through modification of T_{n-1} by arguments (ARG_n) of the player who has to play at that step. The rules for transition from T_{n-1} to T_n are

1. If $r \in R_s^{n-1}$ then $r \in R_s^n$.
2. If $r \in R_d^{n-2}$ and $\forall s \in ARG_{n-1}, \neg C(s) \neq C(r) \wedge \neg C(s) \notin A(r)$, then $r \in R_s^n$; otherwise $r \notin R^n$. Here we should note that the player will not oppose its previous argument. Thus, all unchallenged rules of time $n-2$ are upgraded as strict rules at time n.
3. If $r \in R_d^{n-1}$ and $\forall s \in ARG_{n-1}, \neg C(s) \neq C(r) \wedge \neg C(s) \notin A(r)$, then $r \in R_d^n$. All unchallenged defeasible rules of time $n-1$ are added to T_n as defeasible rules at time n.
4. All rules of ARG_{n-1} are added to T_n as defeasible rules. Here we assume that ARG_{n-1} is valid and that a valid argument, by the above defined precedence relations, is stronger than any contradictory argument of previous step.

It is to be noted that in the first two theories only proof of $+\partial A$ or $-\Delta A$ of a literal A could result. Thus, this framework needs at least three steps in order to determine a winner of a particular game. When the *first* party cannot produce defeasible rules that will defeat contradictory defeasible rules presented by the *second* party at the previous step, the undefeated defeasible rules of the *second* party will be strengthened into strict rules. This allows the *second* party to support its argument and hence prove the critical literal definitely. Let theory T_i be created through modification of theory T_{i-1} by argument (ARG_i) of player 1 and the critical literal A is defeasibly proven $+\partial A$ in this theory. Let at time $i+1$, player 2 cannot produce any arguments defeating the arguments of player 1, then player 1 wins at time $i+2$ as the proof as $+\partial A$ by the strengthening of the rules from defeasible into strict will result in the proof $+\Delta A$ at time $i+2$.

4.4 An example

Now we will illustrate the model of the dialogue game defeasible logic we have proposed with the help of an example. Consider an argumentation game with two players, Alice and Bob. Agent Alice is trying to prove A and agent Bob is trying to prove $\neg A$. At each step of the dialogue game they maintain a current set of rules CR_t, where t is the time. A rule in CR_t, will be represented as $R_i'@t$ and the corresponding rule present in agent's private knowledge will be represented as R_i. Let at time t_1 the game starts and Alice makes the first move as

$$R_1 : \emptyset \Rightarrow B, \quad R_2 : B \Rightarrow A.$$

This will generate two defeasible rule as

$$R_1'(\emptyset \Rightarrow B)@t_1, \quad R_2'(B \Rightarrow A)@t_1$$

and these rules will be inserted into CR_{t_1}. Thus at time t_1 we have a proof of $+\partial A@t_1$. But at time t_2, Bob presents new evidence in order to disprove A. At time t_2 ($t_2 > t_1$), Bob presents the following argument,

$$R_3 : \emptyset \Rightarrow D, \quad R_4 : D \Rightarrow \neg A.$$

This will generate two new defeasible rules

$$R'_3(\emptyset \Rightarrow D)@t_2, \quad R'_4(D \Rightarrow \neg A)@t_2.$$

Now, Bob only attacks R'_2 presented by Alice at previous step by R'_4. Note that as $t_2 > t_1$, R'_4 is stronger than R'_2. At time t_2, R'_1 remains unchallenged and it will remain in CR_{t_2} with a changed time stamp as $R'_1(\emptyset \Rightarrow B)@t_2$. The proof at time t_2 is $+\partial\neg A$. At time t_3, Alice presents the following arguments to prove A,

$$R_5 : B \Rightarrow \neg D, \; R_6 : \emptyset \Rightarrow E \text{ and } R_7 : E \Rightarrow A.$$

So the translated defeasible rules are

$$R'_5(B \Rightarrow \neg D)@t_3, \; R'_6(\emptyset \Rightarrow E)@t_3, \; R'_7(E \Rightarrow A)@t_3.$$

Now $R'3$ is defeated by R'_5 which then makes $R'4$ not applicable. Again the time stamp of R'_1 will be changed and as this rule was unchallenged by Bob at t_2 and its strength will increase as $R'_1(\emptyset \rightarrow B)@t_3$. So the proof at time $t3$ is $+\partial A$. If Bob does not present valid arguments in the next step, Alice wins the game as we allow an agent to upgrade the strength of unchallenged rules in the next time t_4. At t_4 Alice can upgrade the defeasible rules supporting the proof of $+\partial A$ into strict rules and subsequently prove $+\Delta A$.

4.5 Reconsideration and strategy

In our argumentation framework, as in dialogue games in general, reconsideration is not possible as rules are either carried to next step as strict rules or facts, or they are defeated. If the rule is defeated, the agent can no longer argue based on this previous decision. Also, if the status of the rule is strengthened it cannot be defeated any longer. In addition no agent can put forward arguments conflicting with the argument she put forward in previous steps. This means that an agent cannot withdrawn an argument that is used by her opponent to support the opponent critical claim. Notice that in a step an agent can have more than one set of suitable arguments. Here we present some intuitions on how to efficiently distinguish between these choices.

An agent can argue with additional information even if it is not related with the current argument in order to block opponents future arguments at an early stage. For example, if at t_1, Alice presents two arguments as $R_1 : A \Rightarrow B$ and $R_2 : \Rightarrow \neg D$, which is defended by Bob at t_2 by $R_3 : C \Rightarrow \neg B$, thus R_2 is strengthened into a fact at t_3. Now at t_3, Alice passes argument $R_4 : E \Rightarrow B$. Thus, at t_4 Bob has only one argument to defend as $R_5 : D \Rightarrow \neg B$. Bob cannot put forward argument R_5 as R_2 is a fact and stronger than R_5. Hence Alice wins. This will save one step as if Alice had not passed R_2 at t_1, Bob will present R_4 at t_4 and it has to play R_2 at t_5.

5 Related work

Modelling dialogue games in defeasible logic has been addressed by [10,9,11], and the present paper builds on some ideas of [10,9]. [11] focuses on persuasion dialogues and it includes in the process cognitive states of agents such as knowledge and beliefs. In addition it presents some protocols for some types of dialogues (e.g., information seeking, explanation, persuasion). The main reasoning mechanism is based on basic defeasible logic (see Section 3) and it ignores recent development in extensions of defeasible logic with modal and epistemic operators for representing the cognitive states of agents [6,7], and it does not cover adversarial dialogues. [10] provides an extension of defeasible logic to include the step of the dialogue in a very similar to what we have presented in the paper. A main difference is that the resulting mechanism just defines a metaprogram for an alternative computation algorithm for ambiguity propagating defeasible logic while the logic presented here is ambiguity blocking. In [9], the authors focus on rule scepticism and proposes to use a sequences of defeasible (meta) theories, and use meta-reasoning (meta-rules or high level rules) to assess the strength of rules for the theories at lower levels.

Inference System (IS) was proposed in [15] to capture dialogue games. A theory in IS is represented by $T_{IS} = (R, \leq)$ where R is set of strict and defeasible rules and $\leq$ is a partial preorder which resolves any conflicts on precedence between rules. Arguments are *justified*, *overruled* and *defensible* depending on the outcome of the dialogue game. [16] describes the burdens associated with IS. According to [16], there are three kinds of burden as (1) *Burden of persuasion* (2) *Burden of production* and (3) *Tactical Burden of proof*. In [15], players have fixed roles as the burden of prosecution lies on the proponent, leaving the opponent with the burden to *interfere*. [14] modified IS as it proposes switching of roles in *Litigation inference system* (LIS). A theory in LIS is represented as $T_{LIS} = (R, \leq, b_\pi, b_\delta)$ where $(R, \leq)$ is an IS theory. b_π, b_δ are burden of prosecution for proponent and opponent respectively. [17] modifies LIS and proposes *Augmented Litigation inference system* (ALIS) which generates the content of b_π, b_δ as a result of an argument-based reasoning. A theory in ALIS is represented as $T_{ALIS} = (R, \leq)$, where $(R, \leq)$ is an IS theory described by a language which has a predicate *burden*. $burden(p,l)$ means that on the player p is placed the burden of prosecution for the literal l. A dialogue move m has three components: (1) *pl(m)*, the player who made the move (2) *r(m)*, the role of the player, and (3) *a(m)* the argument put forward in the move. ALIS imposes a protocol to be followed by the players. The protocol in ALIS differs from the protocol proposed in LIS in the sense that (1) if in the adjacent previous step the opponent *weakly defeated* an argument proposed by the proponent, then in the current step the proponent can argue that the opponent now has a burden on that literal; and (2) If the players weakly defeat each other while in their opponent role, then the *plaintiff* can argue that *defendant* has the burden of proof.

6 Conclusion and future work

We have presented a dialogue game framework in defeasible logic. We have shown that strength of an unchallenged rule can be upgraded in a dialogue game. We plan to extend the framework to cover more types of dialogue games and to model the different types of burden of proof. We also intend to study cost functions related of to dialogue games and investigate how a strategy can be developed with the aim of maximising the payoff of the game [19]. In addition, this framework could be extended to model the behaviour of an agent φ in a dynamic environment ε. By representing the environment as one of the parties, the agent φ is enabled, by putting forward arguments, to reason on its environment in a both reactive and a proactive way. This would allow for a natural characterisation of the environment as the uncertainty in the environment can be modelled as the private knowledge of ε.

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