# Rules for Formal and Natural Dialogues in Agent Communication

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Abstract. The paper aims to bring together and unify two traditions in studying dialogue as a game: dialogical logic introduced by Lorenzen; and persuasion dialogue games as specified by Prakken. The first approach allows the representation of formal dialogues in which the validity of argument is the topic discussed. The second tradition has focused on natural dialogues examining, e.g., informal fallacies typical in real-life communication. Our goal is to unite these two approaches in order to allow communicating agents to benefit from the advantages of both, i.e. to equip them with the ability to persuade each other not only about facts, but also about the classical propositional *validity of argument* used in a dialogue. To this end, Lorenzen's system needs to be expressed according to the generic specification for natural dialogues proposed by Prakken. As a result, the system proposed in the paper allows the representation and elimination of *formal fallacies* committed during a dialogue.

# **1 INTRODUCTION**

Interest in formal studies of natural dialogue was encouraged by Hamblin's program [6] of designing a game which rules out the use of fallacies during a dialogue. This approach has resulted in many formal systems exploring different informal fallacies (see e.g. [11, 20]). In real-life communication, however, the speakers commit not only informal, but also formal fallacies [3, 19]. A formal fallacy is understood as an argument which is invalid according to some logical system. Amongst fallacies which do not follow the rules of classical propositional logic and are claimed to be common in natural dialogues are, e.g., fallacies of incorrect operations on implication, i.e. *denying the antecedent* ( $\phi \rightarrow \psi$ ,  $\neg \phi$ , therefore  $\neg \psi$ ) and *affirming the consequent* ( $\phi \rightarrow \psi, \psi$ , therefore  $\phi$ ).

A system aiming to disallow the execution of both informal and formal fallacies is proposed by pragma-dialectics [16]. According to *rule* 6 of the critical discussion system [16, p.144], the antagonist may not only challenge the propositional content of premises used by the protagonist, but also the justificatory force (i.e., validity) of his reasoning. The system requires that the defending protagonist has to use rules of some logic. Still, the pragma-dialectical system doesn't provide a formal account of its dialogue or logical rules that would allow the players to argue about the validity of argumentation.

The attempt to formally describe the system of critical discussion was made in [17], however, since a protocol is not fully specified there, it is not possible to evaluate whether and how the proposed dialogue system actually allows formal fallacies to be dealt with. Many other contemporary dialogue games have a logic as a part of the system itself. In such an approach, it is impossible to perform an invalid argument during a dialogue and there are no rules that allow the verification of argument validity and the elimination of formal fallacies.

Research on modelling of communication in multi-agent systems was inspired by dialogue theory of Walton and Krabbe [18] and the speech acts theory of Austin and Searle [1, 15]. In communication languages such as KQML and FIPA speech acts are used to express intentions of their performers and are specified by means of agent's mental attitudes. The most important issue of logical modelling of communication in teamwork, especially during planning is studied in [5]. This work provides a schema of deliberation dialogue along with semantics of adequate speech acts. An implementation of speech acts in a paraconsistent framework is shown in [4]. In this approach, a natural four-valued model of interaction is based on 4QL formalism [12].

The aim of this paper is to make a first key step in including formal fallacies in the formal study of dialogues. We propose a dialogue protocol that allows *classical propositional formal fallacies* to be dealt with in a game for natural dialogue. To this end, we need to start with a system for representing *natural dialogue* and a system for representing *formal dialogue* (i.e. the dialogue in which the validity of argument is the topic discussed). In the first case, we use the framework proposed by Prakken [14], since it provides a generic and formal specification of the main elements of dialogue systems for persuasion. For handling formal fallacies in a dialogue, we use the dialogical logic introduced by Lorenzen [10]. His dialogue games allow the players to prove whether the formula is a tautology of *classical propositional logic*. Note that the aim of this system is not to jointly build an argument:  $\phi$ , therefore  $\psi$ , as in inquiry dialogues (see e.g. [2]), but to allow the participants to play against each other starting with opposing viewpoints on an argument's validity and determine which player wins.

The communication language and the structure of the dialogical logic is, however, different than in dialogue systems designed to simulate natural discourse. For example, in Lorenzen's system the only moves available to speakers are "X attacks A" and "X defends A", while, according to Prakken's specification [14], in dialogue systems for persuasion the legal locutions are: claim  $\phi$ , why  $\phi$ , concede  $\phi$ , retract  $\phi$ ,  $\phi$  since S, question  $\phi$ . This paper demonstrates how those two approaches can be united and unified in order to allow the agents to engage both in natural dialogue about facts and in formal dialogue about the validity of reasoning performed according to classical logic.

The paper is organized as follows. Section 2 introduces an example which illustrates the motivation for the game protocol proposed in the paper. In Section 3 and 4, we give a brief overview of Prakken's generic specification for formal systems of natural persuasion dialogues and Lorenzen's dialogical logic, respectively. In Section 5, we propose a translation of dialogical logic into the generic specification and show how the designed dialogue system: (i) allows the persuasion both about facts and the *classical propositional validity of argument* used in a dialogue, and (ii) allows the representation and elimination of *formal fallacies* committed by dialogue players.

# **2** MOTIVATION EXAMPLE

To show the motivation behind our research, let us review the persuasion dialogue given in [13] in which Paul and Olga discuss whether or not a car which has an airbag is safe. Now, we revise the dialogue to illustrate the main idea of our approach.

- (1) Paul: If a car doesn't have an airbag then it isn't safe. (stating a claim)
- (2) Olga: That is true. (conceding a claim)
- (3) Paul: My car is safe. (making a claim)
- (4) Olga: Why is your car safe? (asking grounds for a claim)
- (5) **Paul**: My car has an airbag and if a car doesn't have an airbag then it isn't safe, thus my car is safe. (making an argument)
- (6) **Olga**: Why do you think that your reasoning is correct? (asking grounds for the argument)
- (7) Paul: It is correct because the scheme p ∧ (¬p → ¬q) → q is a tautology. (offering grounds for the argument)
- (8) Olga: No it isn't. (stating a counterclaim)
- (19) Paul: OK, you are right. I was wrong that the scheme  $p \land (\neg p \rightarrow \neg q) \rightarrow q$  is a tautology. (retract)

In the dialogue, Paul supported his reasoning by a formula which in his opinion was a tautology of classical propositional logic. Olga questioned this and after continuing a discussion for some more time Paul changed his mind. Why did he retract? To answer this question, assume that Paul and Olga attend a course of logic and try to examine the validity of the formula. Their dialogue could be as follows:

- (9) Paul: Let's start a Lorenzen game. (initializing the game)
- (10) I'll show you that the implication  $p \land (\neg p \rightarrow \neg q) \rightarrow q$  is valid. (claiming a formula)
- (11) Olga: I'll help you and assume that  $p \land (\neg p \rightarrow \neg q)$  is true. (attacking implication by stating its antecedent)
- (12) **Paul**: Is *p* true? (attacking conjunction)
- (13) Olga: Yes, it is. (defending conjunction)
- (14) Paul: Is  $\neg p \rightarrow \neg q$  true? (attacking conjunction again)
- (15) Olga: Yes, it is. (defending conjunction by stating implication)
- (16) Paul: Why is  $\neg p \rightarrow \neg q$  true? Can you show this? I'll help you and assume  $\neg p$ . (attacking implication by stating its antecedent)
- (17) Olga: Thus, I state that  $\neg q$  is true. (defending implication by stating its consequent)
- (18) Paul: Well, I have no more available moves. Game is over. (ending the game)

This conversation is based on an indirect method of checking the validity of formulas. The idea consists in assuming the negation of the original claim what is used to deducing that one of its assumptions is a false or an absurd result, and finally to conclude that the initial claim must have been wrong. In particular, in order to show that an implication is a tautology, we assume that its antecedent is true and the consequent is false and try to deduce a contradiction. In the dialogue above, there was no contradiction, thus it means that the examined formula is not a law of classical propositional calculus and can not be used as a (classical) propositional rule of inference.

To summarize, in the first part of the dialogue (the moves 1–8) Paul's reasoning performed in the fifth move was based on a fallacy of denying the antecedent. This mistake was then verified during the discussion. Thus, this dialogue is an example of natural communication in which a formal fallacy was recognized and eliminated. A dialogue aiming to eliminate this mistake is presented in the second part of the example (the moves 9–17) which implements the idea of the dialogical logic of Lorenzen [10]. The aim of such a game is to prove that the sentence is or is not a theorem of the classical propositional logic. Such a dialogue cannot be directly represented by dialogue protocols such as described in [14], since the rules of those systems does not allow the players to prove the validity of arguments used in a dialogue. As a result, in those systems Paul's mistake could not be corrected. Our aim is to propose a protocol which enables the representation of this type of dialogues and express them in Prakken's dialogue game formalism.

# **3 THE SPECIFICATION OF NATURAL DIALOGUE SYSTEMS**

Formal systems for natural dialogue aim to formally model different phenomena, such as, e.g., informal fallacies which are typical in real-life communication (see e.g. [6, 11, 20]). In [14], Prakken presents a general specification of common elements of such systems. In this section, we summarize the most important components.

Every dialogue system has a *dialogue purpose*, a set A of *participants* and a set R of *roles* which participants can adopt during a game. Contents of utterances used by players in dialogues are expressed in a *topic language*  $L_t$ . At the beginning of a dialogue every player s has assigned a (possible empty) set of *commitments*  $C_s \subseteq L_t$ , i.e., sentences to which players are committed to. The set of commitments usually changes during a dialogue. Every dialogue system include the following elements: (i) a **logic** L consisting of a topic language  $L_t$  and a set R of inference rules over  $L_t$ ; (ii) a **communication language**  $L_c$  consisting of a set of locutions; (iii) a set E of **effect rules** of locutions in  $L_c$  specifying the effects of the locutions on the participants' commitments; and (iv) a **protocol** P for communication language  $L_c$ .

The communication language  $L_c$  defines **locution rules** which specify what types of locutions are allowed to be performed during a dialogue game. In [14], Prakken distinguishes the following locutions typically allowed by natural dialogue systems:

- claim  $\phi$  the player asserts that  $\phi$  is the case,
- why  $\phi$  the player challenges that  $\phi$  is the case and asks for reasons why it would be the case,
- *concede*  $\phi$  the player admits that  $\phi$  is the case,
- retract  $\phi$  the player declares that he is not committed (any more) to  $\phi$ ,
- $\phi$  since S the player provides reasons why  $\phi$  is the case,
- question  $\phi$  the player asks another participant about his opinion on whether  $\phi$  is the case.

Locution	Replies
claim $\phi$	why $\phi$ , claim $\neg \phi$ , concede $\phi$
why $\phi$	$\phi$ since S (alternatively: claim S), retract $\phi$
concede $\phi$	
retract $\phi$	
$\phi$ since $S$	why $\psi$ ( $\psi \in S$ ), concede $\psi$ ( $\psi \in S$ )
question $\phi$	claim $\phi$ , claim $\neg \phi$ , retract $\phi$

Table 1. Locutions and typical replies [14, p.172].

The central element of a dialogue game is its **protocol**. Let M be a set of *moves*, i.e., elements of the communication language  $L_c$ . The set of *finite dialogues*  $M^{<\infty}$  is the set of all finite sequences  $m_1, \ldots, m_i$  from M. A *protocol*, specifying the legal moves at each stage of a dialogue, is a function  $P : Pow(L_t) \times D \rightarrow Pow(L_c)$  where  $D \subseteq M^{<\infty}$ . The elements of D are called the *legal finite dialogues*. Typical replies for locutions specified by a protocol are depicted in Table 1.

A set of **effect rules** for  $L_c$  (formally,  $C_s : M^{<\infty} \to Pow(L_t)$ ) specifies for each utterance  $\phi \in L_c$  the effects which this locution makes on the commitments of the participant s. The function  $C_s$  for a sequence of moves assigns a set of commitments. The most common effect rules of dialogue systems as distinguished by Prakken are following (where s denotes a player of a move m which is preceded by a sequence of moves d):

- If  $s(m) = claim(\phi)$  then  $C_s(d, m) = C_s(d) \cup \{\phi\}$ ,
- If  $s(m) = why(\phi)$  then  $C_s(d,m) = C_s(d)$ ,
- If  $s(m) = concede(\phi)$  then  $C_s(d, m) = C_s(d) \cup \{\phi\}$ ,
- If  $s(m) = retract(\phi)$  then  $C_s(d, m) = C_s(d) \{\phi\}$ ,
- If  $s(m) = \phi$  since S then  $C_s(d, m) \supseteq C_s(d) \cup prem(A)$  where prem(A) denotes premises of an argument A.

In some of the dialogue systems, the protocol is enriched with rules regulating turntaking, termination and the outcome of a dialogue. **Turntaking rules** determine a turn of a dialogue i.e., a maximal sequence of moves in which the same player is to move. A *turntaking function* T is a function  $T: M^{<\infty} \to Pow(A)$  which to a sequence of moves assigns a player from the set A. **Termination rules** determine the cases where no move is legal. They should specify the conditions under which the protocol returns the empty set. **Outcome rules** define the outcome of a dialogue.

# **4** A SYSTEM FOR FORMAL DIALOGUES

Now, we briefly describe a system for formal dialogues called dialogical logic introduced by Lorenzen [10] (for its overview in English see e.g. [8,9]). In this approach, dialogues are treated as games in which two parties, opponent and proponent, examine a formula. Their goal is to verify whether this formula is valid (we focus only on the validity of classical propositional logic). A game proceeds according to the set of rules which ensure that the formula is valid iff the proponent has a winning strategy.

In each Lorenzen's game, there are two players involved: *proponent* of the main formula (**P**) and *opponent* of this formula (**O**). During the game they make use of two types of moves: they *attack* or *defend* a formula. Originally, dialogical logic is specified by two kinds of rules: structural rules and particle rules. *Structural rules* determine the general organization of the game while *particle rules* describe the way a formula can be attacked and defended depending on its main connective.

Let us start with description of structural rules. A *dialogue* for a formula (the thesis) A,  $\mathbf{D}(A)$ , is a set of dialogue games consisting of sequences of moves. Depending on which player makes the move, we talk about **P**-statement and **O**-statement. **P** wins a dialogue game if there is a round where after **P** has moved, there is no more move that **O** can legally make. A formula A is valid iff **P** has a winning strategy for A.

Lorenzen approach is an example of a Game-Theoretic Semantics (GTS) [7]. A well-formed formula (WFF) is true under this semantics if and only if Proponent has a winning strategy in a specific game between Proponent and Opponent associated to the WFF. Therefore it is not sufficient for Proponent to win just one actual game, but he must have a winning strategy for every possible game of the associated kind between the two participants.

**Structural rules** for classical propositional logic are specified as follows<sup>4</sup>:

- (D00) P makes the first move, then O and P take turns in performing moves,
- (D10) P may assert an atomic formula only after it has been previously asserted by O,
- (D13) A P-statement may be attacked at most once,
- (E) O can react only upon the immediately preceding P-statement.

	А	Attack	defense	
negation	$\neg A$	A		
conjunction	$A \wedge B$	1?	A	
		2?	В	
alternative	$A \vee B$	?	A	
			B	
implication	$A \to B$	A	B	

Table 2. Particle rules for the basic propositional language

**Particle rules** for basic propositional language are presented in Table 2. In particular, in order to attack a negation, a player has to assert the opposite formula, i.e., if X attacks  $\neg A$  then he asserts A. There is no defense of  $\neg A$  available. If X attacks  $A \land B$  he attacks the first or the second element of the conjunction, i.e. he asks "1?" or "2?". X

<sup>&</sup>lt;sup>4</sup> Original version of dialogue logic was meant for intuitionistic propositional logic and then it has been extended to the classical case.

may choose which conjunct will be attacked first. If X defends  $A \wedge B$ , he asserts that the questioned formula is true making the statement A or the statement B. If X attacks  $A \vee B$ , he performs the move "?" which questions the whole disjunction. If X defends  $A \vee B$ , he asserts either element of the attacked disjunction. If X attacks  $A \to B$ , he asserts the antecedent, making the statement A. If X defends  $A \to B$ , he asserts the consequent of the attacked implication, making the statement B.

# 5 THE SPECIFICATION FOR THE FORMAL DIALOGUE SYSTEM

The paper aims to unite and unify the representation of natural and formal dialogues. To this end, this section shows how dialogical logic could be translated to the specification of natural dialogue systems described in Sect. 2.

#### 5.1 Locution rules

In this paper, a *dialogue goal* of Lorenzen's games is limited to the verification of validity in classical propositional logic. The *set of players* consists of two elements  $\{\mathbf{O}, \mathbf{P}\}$ . The *topic language*  $L_t$  is assumed here to be classical propositional logic. The *communication language* in dialogical logic may seem to be, at the first glance, very limited, since it consists only of two types of actions: *attack* and *defend*. The careful reconstruction of these actions reveals, however, that depending on the structure of attacked or defended formula, those actions can be mapped into various locutions considered by Prakken. The **locutions** allowed in the Lorenzen game are as follows:

**LR1 Claims** *claim*  $\phi$  is performed when a player

- 1. attacks  $\neg A$ , then  $\phi$  is the formula A,
- 2. defends  $A \wedge B$ , then  $\phi$  is the formula A or the formula B,
- 3. attacks  $A \rightarrow B$ , then  $\phi$  is the formula A,
- 4. defends  $A \rightarrow B$ , then  $\phi$  is the formula B;

**LR2** Concessions concede  $\phi$  is performed when a player

- 1. attacks  $\neg A$ , then  $\phi$  is the formula A,
- 2. defends  $A \wedge B$ , then  $\phi$  is the formula A or a formula B,
- 3. attacks  $A \rightarrow B$ , then  $\phi$  is the formula A,
- 4. defends  $A \rightarrow B$ , then  $\phi$  is the formula B;
- **LR3 Argumentations**  $\phi$  *since*  $\psi$  is performed when a player defends  $A \lor B$ , then  $\phi$  is the formula  $A \lor B$  and  $\psi$  is a set which includes the formula A or the formula B;
- **LR4 Challenges** The challenge *why*  $\phi$  is performed when a player attacks  $A \lor B$ , then  $\phi$  is the formula  $A \lor B$ ;
- **LR5 Questions** The question question  $\phi$  is performed when a player attacks  $A \wedge B$ , then  $\phi$  is the formula A or the formula B.

#### 5.2 Protocol

In this section we propose a protocol of a game for a formal dialogue  $d = m_0, m_1, \ldots, m_n$ on the topic A, i.e., for a game  $d \in \mathbf{D}(A)$ . It is built upon the structural and particle rules of dialogical logic. According to the rule (E), in a move  $m_i$  **O** needs only to know the previous move  $m_{i-1}$ . On the other hand, in each move **P** can respond to all moves  $m_1, \ldots, m_i$  performed by **O**, i.e. he needs to remember all the moves of a game.

The protocol is specified by the following **dialogue rules**:

- LO1 In the first move **P** performs *claim*  $\varphi$  where  $\varphi$  is a formula to be examined; next players performs one locution at each turn;
- **LO2 P** cannot perform *claim*  $\varphi$  where  $\varphi$  is a proposition; he can state that  $\varphi$  is true executing *concede*  $\varphi$  but this move can be performed only if **O** claimed  $\varphi$  before;
- LO3 After *claim*  $\varphi$  a player can perform:
  - 1. no move, if *claim*  $\varphi$  is an attack on negation,
  - 2. *claim*  $\psi$ , if  $\varphi$  is the implication under the attack and  $\psi$  is the antecedent of  $\varphi$ , for **P** with respect to the limits described in **LO2**,
  - 3. *concede*  $\varphi$ , if the player is a proponent and  $\varphi$  is a proposition which is used as an attack on negation or implication or in defence of conjunction,
  - 4. *claim*  $\psi$ , if  $\varphi$  is a negation of  $\psi$ , for **P** with respect to the limits described in **LO2**,
  - 5. question  $\psi$ , if  $\varphi$  is a conjunction and  $\psi$  is one of its operands,
  - 6. why  $\varphi$ , if  $\varphi$  is a disjunction,
  - 7. *claim*  $\psi$ , if  $\varphi$  is an implication and  $\psi$  is its antecedent, for **P** with respect to the limits described in **LO2**,
  - 8. attack or defence any sentence uttered before, if a player is a proponent,
  - 9. no move for an opponent, if *claim*  $\varphi$  is a defence executed by a proponent and the opponent has attacked this defence before;
- **LO4** After *concede*  $\varphi$  performed by a proponent, where  $\varphi$  is a proposition, a player can perform:
  - 1. *claim*  $\psi$ , if *concede*  $\varphi$  is an attack on implication and  $\psi$  is the consequent of the attacked implication or *claim*  $\psi$  is a defence of the implication,
  - 2. no move, if *claim*  $\varphi$  is a defence executed by a proponent and the opponent has attacked this defence before;
- **LO5** After  $\varphi$  since  $\Psi$ , where  $\Psi = \{\psi\}$  a player can perform:
  - 1. *concede*  $\psi$ , if the player is an opponent and *concede*  $\psi$  is at least the second attack on  $\varphi$ ,
  - 2. *claim*  $\varphi$ , if  $\psi$  is a negation of  $\varphi$ , for **P** with respect to the limits described in **LO2**,
  - 3. question  $\varphi$ , if  $\psi$  is a conjunction and  $\varphi$  is one of its operands,
  - 4. why  $\psi$ , if  $\psi$  is a disjunction,
  - 5. *claim*  $\varphi$ , if  $\psi$  is an implication and  $\varphi$  is its antecedent, for **P** with respect to the limits described in **LO2**,
  - 6. attack or defence any sentence uttered before, if a player is a proponent,
  - 7. no move for an opponent, if *claim*  $\varphi$  is a defence executed by a proponent and the opponent has attacked this defence before;

- **LO6** After why  $\varphi$  a player can perform:
  - 1.  $\varphi$  since  $\psi$ , for **P** with respect to the limits described in **LO2**,
  - 2. attack or defence any sentence uttered before, if a player is a proponent;
- **LO7** After question  $\varphi$  a player can perform:
  - 1. claim  $\varphi$ , for **P** with respect to the limits described in **LO2**,
  - 2. attack or defence any sentence uttered before, if a player is a proponent.

#### 5.3 Effect rules

The dynamics of participants' commitments in the Lorenzen game will be showed by **hypothetical commitment base**. During the game, new formulas are added to this base and no formulas are deleted, since in this system the players are not allowed to retract. Let  $d \in M^{<\infty}$  be a finite dialogue game, m – a legal move, s(m) denote a move of a player s, and  $\varphi, \psi \in L_t$ . For a formal dialogue  $d = m_0, m_1, \ldots, m_n \in \mathbf{D}(A)$ , the rules for hypothetical commitment base  $C'_s$  of a player  $s \in \{\mathbf{O}, \mathbf{P}\}$  are specified as follows:

- if  $s(m) = claim(\varphi)$  then  $C'_s(d, m) = C'_s(d) \cup \{\varphi\}$ , i.e. after  $claim(\varphi)$  the formula  $\varphi$  is added to the hypothetical commitment base,
- if  $s(m) = why(\varphi)$  then  $C'_s(d,m) = C'_s(d)$ ,
- if  $s(m) = concede(\varphi)$  then  $C'_s(d, m) = C'_s(d) \cup \{\varphi\}$ ,
- if  $s(m) = (\varphi \lor \psi)$  since  $\varphi$  then  $C'_s(d, m) = C'_s(d) \cup \{\varphi\}$ , i.e. after  $(\varphi \lor \psi)$  since  $\varphi$  the formula  $\varphi$  is added to the hypothetical commitment base,
- if  $s(m) = question(\varphi)$  then  $C'_s(d, m) = C'_s(d)$ .

If a Lorenzen game is embedded in a natural dialogue game, then an examined thesis A will be added to the opponent' **main commitment store**  $C_s$  in the natural dialogue game if the proponent wins, and it will be deleted from the proponent' main commitment store  $C_s$  if the proponent loses. If in  $m_n \mathbf{O}$  does not have any legal move to perform then  $C_{\mathbf{O}}(d, m_{n+1}) = C_{\mathbf{O}}(d, m_n) \cup A$ , otherwise  $C_{\mathbf{P}}(d, m_{n+1}) = C_{\mathbf{P}}(d, m_n) - A$ .

As a result, the proponent' victory counts as the opponent' move *concede* (A) in the main natural dialogue game, while the opponent' victory fulfills the role of the proponent's *retract* (A) in the main game.

#### 5.4 Outcome, turntaking and termination rules

**Outcome rules** in a dialogue game are specified as winning or losing of **P**. In the case, when the last move is made by **O** and **P** does not have any legal move to perform, **P** loses.

A **turntaking rule** in a dialogue game is determined by the structural rule (D00), i.e., **P** makes the first move, then **O** and **P** make one in one turn.

**Termination rules** determine all cases in which players have no move to perform. In a Lorenzen game, **O** cannot reply for a locution *concede* (p), for an atomic formula p, if *concede* (p) was not an attack on implication  $p \rightarrow \varphi$  or a locution  $(p \lor \psi)$  since p. All other moves of the proponent can be attacked by **O**. On the other hand, a proponent **P** has no answer for a locution executed by **O**, if this requires from him to state an atomic formula p and **P** cannot do this because there is no previous move in which **O** claimed p and there is no other previous move to which **P** can refer to (i.e. attack or defend).

#### 5.5 Transitional rules

In this section it is specified how the two protocols for natural and formal persuasion dialogues are combined. To model how the protocol for formal dialogues is embedded in the protocol for natural dialogue there is a need to introduce two new locutions: *InitLor* and *EndLor*. The new **locution rules** are described below:

- **TR1 Initialization** The locution *InitLor*  $\phi$  breaks the natural dialogue and initializes the Lorenzen game for formula  $\phi$ ;
- **TR2 Ending** The locution *EndLor*  $\phi$  ends the Lorenzen game for  $\phi$  and resumes the braked natural dialogue.

In our approach it is assumed that the Lorenzen game for a formula  $\phi$  starts when one of the players challenges this formula or states that it is not a tautology. Then, the players examine  $\phi$  in accordance with the rules of the Lorenzen game. As we noticed in Sect. 4,  $\phi$  is a tautology of classical propositional logic iff the proponent for  $\phi$  has a winning strategy for every possible game for  $\phi$ . In other words, parties must play all games and if **O** wins at least one of them **P** loses and  $\phi$  is not a tautology<sup>5</sup>. Thus, any time **P** wins a game, **O** can switch to a new game if only such a game exists. There are free cases in which a game can be extended in such a way that it will generate two distinct (new) games:

- if O defends disjunction φ ∨ ψ he can extend a game with two moves: (1) defence φ or (2) defence ψ;
- 2. if **O** attacks conjunction  $\phi \land \psi$  he can extend a game with two moves: (1) question  $\phi$  or (2) question  $\psi$ ;
- 3. if **O** defends implication  $\phi \rightarrow \psi$  he can extend a game with two moves: (1) attack on  $\phi$  or (2) defence  $\psi$ .

The new **dialogue rules** are summarised below:

- **TO1** The locution *InitLor*  $\phi$  can be performed as an answer for the locution *why* (the formula  $\phi$  is a tautology) or the locution claim ( $\neg$  the formula  $\phi$  is a tautology) executed in a natural dialogue;
- **TO1** After *InitLor*  $\phi$  the performer executes *claim*  $\phi$ , i.e., becomes the proponent for this formula;
- **TO3** The locution *EndLor*  $\phi$  can be performed if a player has no legal move according to the dialogue rules **LO1-LO7** and he cannot switch to a new game for  $\phi$  (no strict repetitions are allowed);
- **T04** After *EndLor*  $\phi$ , if the performer is a proponent for  $\phi$ , he performs *retract* ( $\phi$  is a tautology) which is the first move in the resumed natural dialogue; otherwise (i.e. if the performer is an opponent for  $\phi$ ), he executes *concede* ( $\phi$  is a tautology) and thus resumes the natural dialogue.

<sup>&</sup>lt;sup>5</sup> In the case of classical propositional logic which we take into consideration it is not possible for the proponent to loose because the winning strategy is not obeyed.

#### 5.6 Example

According to the new specification of the protocol for formal dialogues, the dialogue game examining a validity of Paul's argument can be embedded into the natural dialogue about the safety of Paul's car in the following way:

**P**<sub>1</sub>: *claim* ( $\neg$  airbag  $\rightarrow \neg$  safe) **O**<sub>2</sub>: *concede* ( $\neg$  airbag  $\rightarrow \neg$  safe) **P**<sub>3</sub>: *claim* (safe)  $O_4$ : why (safe) **P**<sub>5</sub>: safe since (airbag  $\land$  ( $\neg$  airbag  $\rightarrow \neg$  safe)  $\rightarrow$  safe) **O**<sub>6</sub>: why (airbag  $\land (\neg \text{ airbag} \rightarrow \neg \text{ safe}) \rightarrow \text{ safe})$ **P**<sub>7</sub>: (airbag  $\land$  ( $\neg$  airbag  $\rightarrow \neg$  safe)  $\rightarrow$  safe) since ( $p \land (\neg p \rightarrow \neg q) \rightarrow q$  is a tautology) **O**<sub>8</sub>: *claim* ( $\neg$  the formula  $p \land (\neg p \rightarrow \neg q) \rightarrow q$  is a tautology) **P**<sub>9</sub>: *InitLor*  $(p \land (\neg p \rightarrow \neg q) \rightarrow q)$  $\mathbf{P}_{10}: claim \left( p \land \left( \neg p \to \neg q \right) \to q \right)$ **O**<sub>11</sub>: *claim*  $(p \land (\neg p \rightarrow \neg q))$  $P_{12}$ : question (p)  $O_{13}$ : claim (p) **P**<sub>14</sub>: question  $(\neg p \rightarrow \neg q)$ **O**<sub>15</sub>: claim  $(\neg p \rightarrow \neg q)$ **P**<sub>16</sub>: claim  $(\neg p)$  $\mathbf{O}_{17}$ : claim  $(\neg q)$ **P**<sub>18</sub>: EndLor  $(p \land (\neg p \rightarrow \neg q) \rightarrow q)$ **P**<sub>19</sub>: retract  $(p \land (\neg p \rightarrow \neg q) \rightarrow q \text{ is a tautology})$ 

In this dialogue, the moves  $P_1-O_8$  constitute the first part of a discussion (a natural dialogue) in which Paul makes a claim that his car is safe. The claim is obtained on the basis of reasoning (formulated in  $P_5$ ) which in his opinion is valid. Then, in the move  $P_9$  Paul starts Lorenzen game and in moves  $P_{10}-O_{17}$  Paul and Olga play a formal dialogue trying to verify a law used as a premise in Paul's reasoning. After the move  $O_{17}$ , Paul has no more legal moves available which means that he loses and in the move  $P_{18}$  ends the game. As a result, in the natural dialogue he retracts in the move  $P_{19}$ .

This example shows how natural and formal dialogues can be performed in one dialogue game. Our proposal of specification of the rules of dialogical logic enables to execute a Lorenzen game using it for checking the validity of reasoning. Thus, the protocol proposed in this paper offers a tool for eliminating formal fallacies (such as a fallacy of denying of antecedent in  $P_5$ ) committed during a natural dialogue.

# 6 CONCLUSION

The paper proposed a protocol for a game in which the players can persuade each other not only about facts, but also about the classical propositional validity of formulas. The main contribution is the translation of Lorenzen dialogical logic from the original description to the generic specification proposed by Prakken. As a result, the Lorenzenlike formal dialogue can be easily embedded into the Prakken-like natural dialogue without a need of changing a communication language. The agents communicating about facts can shift to a dialogue allowing them to check the validity of one player's argumentation executed according to the classical propositional logic. In consequence, the players will be allowed to commit a formal fallacy, but the game protocol provides a machinery for eliminating it by proving that the player has committed this fallacy.

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