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ARGUMENTATION AND INFERENCE: A UNIFIED APPROACH

ABSTRACT: We propose in this paper to use Ludics as a unified framework for the analysis of dialogue and the reasoning system. Not only is Ludics a logical theory, but it may also be built by means of concepts of game theory. We first present the main concepts of Ludics. A *design* is an abstraction and a generalization of the concept of proof. Interaction between designs is equivalent to cut elimination or modus ponens in logical theories. It appears to be a natural means for representing dialogues and also for reasoning. A design is a set of sequences of alternate *actions*, similar to a move in game theory. We apply Ludics to argumentative dialogues. We discuss how to model the speech acts of argumentative dialogues in terms of *dialogue acts*. A dialogue act is given by a Ludics action together with the expression that reveals the action in a turn of speech. We show also how arguments may be stored in a *commitment state* used for reasoning. Finally we revisit an example of juridical dialogue that has been analyzed by Prakken in a different framework.

1. INTRODUCTION

The domain of argumentative dialogues has received particular attention in the last thirty years. Studying them requires incorporating both a precise linguistic analysis of their structure and tools for reasoning with arguments and knowledges coming from the different participants of the dialogues. Game theory and nonmonotonic logics are the two main formalisms that have been used for this purpose, *e.g.* Walton (1985); Mackenzie (1990); Poesio & Mikheev (1998); Loui (1998); Prakken (2008); Lascarides & Asher (2009). Game theory is a natural setting for taking into account the alternating structure of a dialogue: a dialogue is a play and a locutor wins when her last argument cannot be refuted by her interlocutor. Arguments are moves and each turn of speech introduces elements for further actions. Furthermore, at each step, (counter-)arguments, *i.e.* facts or propositions, uttered by an interlocutor should be logically checked against the locutor's knowledge, and locutor's arguments should be compared and evaluated in order to be able to choose the best one with respect to a current situation. In order to achieve this last objective nonmonotonic logics are used. Nevertheless, it seems that the most important argument in favor of nonmonotonicity concerns the rational management of propositions: they may be contradicted or their premises may be fallacious, their validity may be questioned.

We propose to use Ludics (Girard 2001) as a unified framework for the analysis of dialogue and the reasoning system. In some sense, our approach, initiated by Lecomte & Quatrini (2010), falls within game theory. Not only is Ludics a logical theory, but it may be built by means of concepts of game theory (Basaldella & Faggian 2009). However, it is noticeable that Ludics is first a theory of interaction: plays are not given a priori but are the result of the interaction between two players. In this paper, we show how a dialogue between two locutors may be incrementally modeled as an interaction between two *designs*, which are the elementary objects in Ludics. Besides designs representing the dialogue itself, each locutor is given a *commitment state* that contains the pieces of information or knowledges she is committed to by her interventions. These pieces of information are also represented as designs. Thanks to the Ludics framework, it is possible to make inferences, to draw conclusions from these designs, and in particular to model contradictions that may arise during the dialogue. The full question of inferring the best argument for subsequent interventions, given the current situation, is outside the scope of this paper.

In section 2, we present the main concepts of Ludics. A *design* is an abstraction and a generalization of the concept of proof. Interaction between designs is equivalent to cut elimination or modus ponens in logical theories. It appears to be a natural means of representing dialogues and also for reasoning. A design is a set of sequences of alternating *actions*, similar to a move in game theory. We apply Ludics to argumentative dialogues in section 3. We give an interpretation of elementary communicational facts as *dialogue acts*. A dialogue act is given by a Ludics action together with the expression that reveals the action in a turn of speech. We discuss speech acts as they appear in argumentative dialogues in terms of sequences of dialogue acts. A dialogue is then the interaction between two designs, one for each locutor, consisting of such dialogue acts. Finally, we show how arguments given in interventions may be used for reasoning. Each locutor is given a *commitment state* that is a set of designs. For each locutor, designs in her commitment state together with her design representing her viewpoint on the dialogue may interact in order to manage the evolution of her state of commitments. Section 4 is devoted to the analysis of a juridical dialogue. We revisit an example already analyzed in Prakken (2008) and show in particular that interventions of the judge may be interpreted in a natural way as forced interventions of one or the other party.

2. LUDICS: A THEORY OF LOGIC BASED ON INTERACTION

Ludics (Girard 2001) is a logical framework developed by J.-Y. Girard around 2000. The motto underlying Ludics is: *interaction is a central concept in logic*. This motto can be seen as expressing the fruitful connection between logic and computer science, namely the Curry-Howard isomorphism. Recall that this isomorphism establishes a perfect correspondence between programs and their execution on one side, and formal proofs and cut elimination on the other side. A cut between conclusions of proofs enables an interaction between these proofs, when one of the formulas is the conclusion of one proof,

whereas the other is a hypothesis of the other proof. Called modus ponens, it is the main ingredient of reasoning; one of the main results of proof theory states that it is always possible to *normalize* a proof, *i.e.* to transform a proof with cuts into an equivalent proof without cuts. The dynamics of computation may therefore be considered as the heart of logic.

After decades of work studying the properties of this dynamics and expanding its scope of relevance, Ludics reverses the priorities of the concepts involved. Traditionally, formulas and proofs are first set, the cut being one of the rules used in the definition of what is a correct proof. The cut elimination procedure completes the picture by adding a dynamics. Then, progressively, to ensure dynamic properties, formulas and proofs have been refined. Linear Logic (Girard 1987) illustrates these changes: conjunction and disjunction connectives are each replaced by two versions, additive and multiplicative, and the framework of proofnets gives a geometrical presentation to proofs where the cut elimination property still appears as a property given a posteriori, *i.e.* as a reduction of such graphs. Contrary to this, in Ludics, cut, *i.e.* interaction, is a primitive concept. Neither formulas nor proofs are considered primitive but are rather *designs*, whose sole purpose is that they carry on the interaction. In fact, interaction takes place between two designs as a step-by-step progression through two dual paths, one path in each design. A design is then nothing else but a set of potential paths where interaction may take place. Moreover, a design is essentially defined by its counter-designs: those with whom it interacts.

The basic steps of interaction (called *actions* in Ludics) correspond to the basic steps of cut elimination. They make possible the exploration of a design in the way that one can explore a formula through its main connective to its subformulas, and so on. However, a design abstracts from the notion of formula: a design has only loci, *i.e.* addresses, through which interaction passes. When a set of designs is given, the space where interaction with these designs may take place is also given. This space is defined by all the counter-designs of each design of this set. This gives an external viewpoint on designs, from which one may observe regularities. Formulas may then be retrieved as sets of designs closed relative to these counter-designs. Indeed, exploring a set of designs reduces to exploring each design of this set.

When it is closed, a set of designs describes all the ways to explore the object it represents, up to its undecomposable elements. This has to be related to the concept of a formula, defined inductively by its connectives and the subformulas that compose it including propositional variables or constants. Moreover, and this is an essential property of Ludics, some designs associated with a formula may be proofs (of this formula): those designs that satisfy suitable properties, among which, precisely, the fact that the exploration can always continue until a suitable term. So, the truth of a formula requires the existence of some proof belonging to the set of designs and associated with the formula.

The formalization of argumentation in Natural Language that we propose takes as "primitive" objects of interaction: actions and designs, taken prior to their logical reconstruction. The fact that interaction is the fundamental concept of Ludics justifies its relevance to the study of dialogues, hence also to Natural Language (Lecomte & Quatrini 2011). Remark that Ludics has also been used in the same spirit for formalizing web processes (Fouqueré 2011).

In the following, we present concepts of Ludics, *i.e.* mainly actions, designs and interaction. Anticipating the modeling of argumentation that will be more formally presented in section 3, we illustrate these concepts by means of a small dialogue. The reader may find exhaustive presentations of Ludics in Girard 2001; Curien 2005a,b.

Example 1. *The dialogue is between an examiner and Theo. It is part of a Turing test: the examiner has to understand if Theo is a machine or a human.*

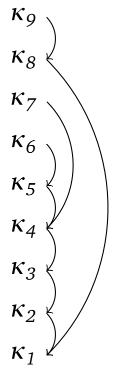
I_1	*Examiner*	*You want to speak about music or math?*
I_2	*Theo*	*Music.*
I_3	*Examiner*	*What kind of music do you play?*
I_4	*Theo*	*I play piano, and I sing also.*
I_5	*Examiner*	*Play us a piece of piano.*
I_6	*Theo*	*There is no instrument in this room.*
I_7	*Examiner*	*Then sing something.*
I_8	*Theo*	*I prefer to speak of math.*
I_9	*Examiner*	*What is 11 and 11 ?*
I_{10}	*Theo*	*22.*
I_{11}	*Examiner*	*And 512+512?*
I_{12}	*Theo*	*I've never been good at mental arithmetic.*
I_{13}	*Examiner*	*It does not matter. Try.*
I_{14}	*Theo*	*Around 1000.*

2.1. Actions, the Justification Relation and Designs

In Ludics, primitive elements of interaction are **actions**. Actions are polarized and appear as dual pairs: for each positive action (resp. negative) κ, there exists a dual negative action (resp. positive) $\overline{\kappa}$ and $\overline{\overline{\kappa}} = \kappa$. As in game theory, a **justification** relation between actions is given. Moreover, actions are organized in alternate sequences called **chronicles** in Ludics. These sequences should satisfy the following conditions: (i) a positive action can be either *initial* or *justified* by a negative action that precedes it in the sequence, (ii) a negative action, except the first, is justified by the positive action immediately preceding. Following the metaphor of games, these alternate sequences of actions can be seen as *plays* that can be grouped to form *strategies* called designs in Ludics (Basaldella & Faggian 2009). Thus, **designs** are sets of chronicles that may be interwoven to give rise to what transpires during an interaction. Not all sets of chronicles can be designs: in particular a design should be organized as a forest, with only one root when the initial action is positive.

Example 2. *We consider only the first nine interventions of example 1. As a rough approximation, each turn of speech is associated with one action:* $\kappa_1, \ldots, \kappa_9$.

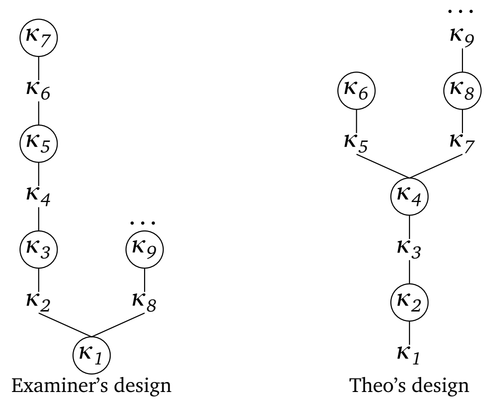
The sequence of actions $\kappa_1, \ldots, \kappa_9$ is a *play* in terms of game semantics. The justification relation between the actions $\kappa_1, \ldots, \kappa_9$ is given on the right where an arrow from action κ to action κ' denotes that κ is justified by κ'.
- The first action κ_1 is initial: with intervention I_1, the examiner initiates the dialogue.
- Actions κ_2 and κ_8 are justified by this first action κ_1: the dialogue begins about music (intervention I_2) then the discussion turns on math (intervention I_8).
- Intervention I_4 (action κ_4) also introduces two elements, piano and song, that are foci of interventions I_5 and I_7 (resp. actions κ_5 and κ_7). The other actions are justified by the actions immediately preceding them.



A play with the justification relation.

The framework of Ludics allows for rebuilding from a play, the shape of information that has to be minimally present in the two parts, *i.e.* the two locutors in the example. The play is the trace of interaction given by the dialogue. For that purpose, each action κ_i present in the play gives rise to two dual actions, one for each reconstructed design: a positive action noted $\textcircled{\kappa_i}$ and a negative action still noted κ_i.

The principle for rebuilding the designs is the following one:
- Let $\textcircled{\kappa}$ be a positive action present in a design, if κ' is justified by κ then κ' appears as a (negative) daughter in the design. This is the case with κ_2 and κ_8 with respect to $\textcircled{\kappa_1}$.
- Let κ be a negative action present in a design, then it has only one (positive) daughter $\textcircled{\kappa'}$ in this design, where κ' follows κ in the play. Hence, for example, $\textcircled{\kappa_3}$ is the (unique) daughter of κ_2.
The design on the left has two chronicles. The design on the right is incomplete as one of its chronicles has a negative action as leaf: each chronicle should end with a positive action. We only give here part of the dialogue.



Two designs

We rebuilt designs from the result of an interaction. In the next subsection, we define how designs interact when they are given a priori: the play is then a travel through the two designs.

It is worthwile at this point to provide a few general comments on the example. First, representing the dialogue as a trace (a sequence of visited actions) of an interaction between two designs allows for recovering the two points of view in a dialogue, one for each locutor. Each action as it appears as an intervention in the dialogue is positive for the locutor and negative for her addressee. More precisely, a positive action in some locutor's design corresponds to an active role of this locutor. A negative action in the locutor's design corresponds to a passive role, namely the registration of an intervention of the interlocutor. In the previous figure, the design on the left is the *point of view* of the examiner while the design on the right is the *point of view* of Theo (with respect to the dialogue). Second, as we shall see more precisely with the definition of an action in the next subsection, a positive action gives rise to *potential* foci of next actions, *i.e.* next interventions, for pursuing the dialogue. As such, there may be more loci induced by an action than what is (minimally) required in the dialogue. For example, the dialogue between Theo and the examiner may finish before intervention I_8, hence speaking math (proposed by intervention I_1) may be useless. Third, polarity of actions as stated above has nothing to do with distinctions such as question/answer or affirmative/negative utterances: it is only a matter of who speaks.

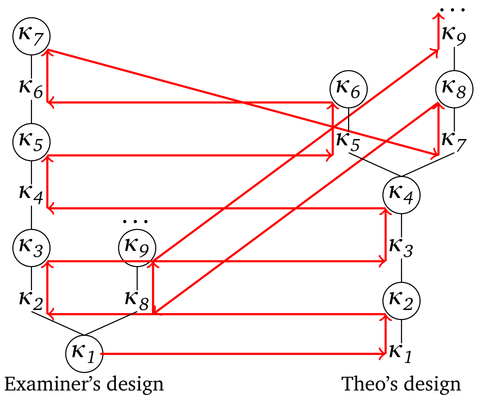
2.2. Interactions: Elementary Facts

An **interaction** occurs between two designs when each of them contains a path corresponding to the other path. It involves travelling through these two designs as follows:

- It starts with the object that contains as root a positive action (hence unique).
- Each time it goes through a positive action ⓚ of one of the two designs, the travel continues in the other design on the negative action κ that is dual to ⓚ (when the negative action κ exists), then continues on the only positive action that follows this negative action in the same design.

This process continues as long as positive actions that are visited have a corresponding negative action in the other design. If such a negative action is not found, the process *diverges*, *i.e.* fails.

The **trace** of an interaction is given by the sequence of pairs of dual actions followed during this interaction.



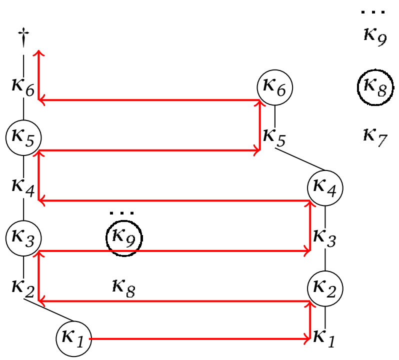
Interaction between two designs

To be complete, designs in Ludics are made of two kinds of actions:

besides proper actions (as the ones used before) that may be positive or negative, there exists a special (positive) action called the **daimon** and noted †. This action may appear several times in a design, but always as the last action of a chronicle: a daimon is used as the final element of an interaction, or in more abstract words the final convergence of the interaction. Interaction between designs may now be fully defined: The travel begins in the design that contains the positive version of two corresponding initial actions. Each time the travel reaches a positive action ⓚ of one of the two designs, the travel goes to the negative dual action κ, if it exists, then it continues with the unique positive action that follows κ in this design **until the positive action that is reached is the daimon**. In that case, the interaction is said to be *convergent*, otherwise (*e.g.* the negative dual action does not exist) it is said to be *divergent*. In dialogues, a convergent interaction means a dialogue that went well.

Example 3. *Let us consider a variant of example 1. The interaction is modeled in figure at the bottom of the page. The intervention $I_7{}'$ is rendered as a daimon as it ends the dialogue.*

I_1	*Examiner*	*You want to speak about music or math?*
I_2	*Theo*	*Music.*
I_3	*Examiner*	*What kind of music do you play?*
I_4	*Theo*	*I play piano, and I sing also.*
I_5	*Examiner*	*Play us a piece of piano.*
I_6	*Theo*	*There is no instrument in this room.*
$I_7{}'$	*Examiner*	*Sorry. Bye.*



Note that in example 3, some actions are not present in the designs while they were present in the interaction presented in example 2: the negative action κ_7 and pairs of actions κ_8 and κ_9. Indeed, in this paper, we model dialogues *as* they are given, and do not present designs that may give rise to some dialogue: we model a dialogue in such a way that actions present in designs are exactly those that are visited during the interaction.

We must remark that having such minimal designs or designs with more actions which could be given a priori does not change the way interaction occurs.

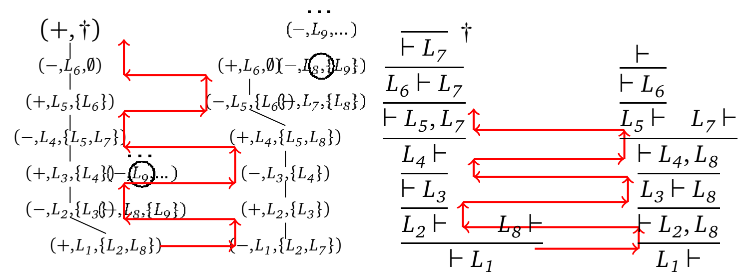
We must also remark that having designs minimal w.r. to the dialogue or not does not change the actions (and their interpretation). Why? Because an action in Ludics is concretely defined as either the daimon $(+,\dagger)$ or a triple (ϵ, L, I) where:

- ϵ is the *polarity* of the action, either positive or negative.
- L is the address or *locus* of the action, concretely a sequence of integers, that locates the action.
- I is a *ramification*, *i.e.* a finite set of integers.

The action can be present in a design if its locus either is *initial* or is generated by an ancestor node in the tree. In fact a design is given with a set of initial loci, its *base*. The generation of loci is done in the following way. If the action (ϵ, L, I) is present in a chronicle of a design then actions on descendant nodes may be located on addresses $L.i$ where $i \in I$: the action opens new loci for continuing the design, *i.e.* the dialogue. For example, if we consider intervention I_1 in example 1, still anticipating the next section, we can say that it introduces two new loci, one for "Music" and one for "Math". Hence the action $\textcircled{\kappa_1}$ is formally given as $(+, L, \{1,2\})$ (if L is the initial locus): loci $L.1$ and $L.2$ are possible loci of continuations. And negative actions κ_2 and κ_8 are respectively given as $(-, L.1, \{0\})$ and $(-, L.2, \{0\})$. In other words, the ramification of an action contains the various loci for continuing the dialogues, these loci may or may not be used as foci of ulterior actions in the design. Presenting addresses as sequences of integers allows for taking into account the justification relation: locus $L.i$ is justified by locus L.

In the following, we make use of *names* instead of *sequences of integers* in order to make the examples easier to read. The reader should note that distinct actions in the same chronicle have distinct foci, hence names are distinct. Furthermore, we shall present designs in a proof-style manner. We hope the following translation of our previous example is sufficiently obvious.

Example 4. *The designs given in example 3 are reproduced below on the left where actions are replaced by their content (circled actions have a positive polarity, . . .). It may also be presented in a proof-style manner (designs on the right).*



We should remark that, at that level of description of the dialogue of example 1, the linguistic expression "Music or Math" is rendered as a *set* of two values and in fact the two cases are used in the subsequent dialogue, one at a time. Such a case is said to be *multiplicative*. If, in place of intervention I_1, we have intervention "What do you want to speak about? Choose one subjet between music or math.", it should be noted that one choice excludes the other with respect to some dialogue. Such a case is said to be *additive*. Other simple examples of additive situations are given by Yes/No questions. Thus, example 1 may be the following of a dialogue with interventions I_0: "Do you want to speak?" from the examiner and an answer from Theo "Yes". Obviously, there is no possibility of accepting "Yes" and then going back to an answer "No" in the subsequent dialogue (as in the case with Math and Music), however there may be *distinct* dialogues for each answer: the two situations are additive. Ludics is able to take into account the distinction between multiplicative and additive situations: if a positive action $(+, L, I)$ is travelled during an interaction, then for each $i \in$

I exactly one of the negative actions of the form $(-, L.i, J_i)$ may be travelled during this interaction. The fact that each i may be used corresponds to multiplicativity, the fact that there cannot be more than one action for each i corresponds to additivity.

Finally, dialogues may behave badly because of misunderstandings, or irrelevant answers. Ludics allows for taking into account such situations: at each step, interaction may progress if there exists a negative action corresponding to the positive one that is considered. This would not be the case with a variant of example 1 if the examiner proposes something that is not understandable by Theo. In such a situation, the interaction is *divergent*.

Example 5. *In the following dialogue, the proposition of the examiner is incomprehensible by Theo (supposing Theo does not understand german), hence the dialogue is divergent: ramifications of the two actions are different. Obviously such a divergence may occur at any stage of a dialogue.*

I_1	*Examiner*	*Willst du etwa Mathematik oder Musik sprechen?*
I_2'	*Theo*	*???*

$$\underset{\text{Examiner}}{(+, L_1, \{L'_2, L'_8\}) \longrightarrow ?} \qquad \underset{\text{Theo}}{(-, L_1, ???)}$$

2.3. *How Logic is retrieved*

A thorough presentation of Ludics and the way it allows for having a model of Linear Logic is outside the scope of this paper. We refer the reader to Curien 2005a,b. We only mention a few elements that may be of interest for our purpose, in particular how orthogonality is defined and what corresponds to the axiom such as $A \vdash A$.

The result of the interaction between two designs $\mathscr{D}$ and $\mathscr{E}$ either diverges or is still a design. If it exists, it is noted $[[\mathfrak{D}, \mathfrak{E}]]$: roughly speaking, it contains the actions of $\mathfrak{D}$ and $\mathfrak{E}$ except the dual ones. The fact that $[[\mathfrak{D}, \mathfrak{E}]]$ exists and is reduced to a daimon is the key ingredient in rebuilding logic: $\mathfrak{D}$ and $\mathfrak{E}$ are orthogonal, written $\mathfrak{D} \perp \mathfrak{E}$ if their interaction converges and the result is reduced to a daimon. To go further, let D be a set of designs (based on the same initial loci and the same polarity), the orthogonal of D, noted $D^{\perp}$, is the set of designs that are orthogonal to each design of D. As usual with such a definition, $D^{\perp\perp}$ is the *closure* of the set D as $D^{\perp} = D^{\perp\perp\perp}$. Finally, a set of designs D such that $D = D^{\perp\perp}$ is called a **behaviour**. Logics may then be rebuilt: a formula is denoted as a behaviour, linear connectives are retrieved by means of adequate operations on designs and on sets of designs, a proof of a formula is interpreted as a design in the behaviour that, mainly, has no daimon.

The interaction with a particular design, called the *fax* and noted $\mathscr{F}ax_{\xi,\xi'}$ corresponds to a cut between a proof of a sequent $\vdash A$ and the axiom $A \vdash A$. However what is obtained when doing an interaction between a design $\mathscr{D}$ of base ξ and a fax $\mathscr{F}ax_{\xi,\xi'}$ is a design isomorphic to $\mathscr{D}$ but of base ξ': the fax delocalizes the design which it interacts with. The fax is recursively defined in the following way, where $\mathscr{P}_f(\mathbb{N})$ is the set of finite sets of integers:

$$\dfrac{\dots \quad \dfrac{\dots \quad \overset{\mathscr{F}ax_{\xi'.i,\xi.i}}{\xi'.i \vdash \xi.i} \quad \dots}{\vdash \xi.I, \xi'}\,(+,\xi',I) \quad \dots}{\xi \vdash \xi'}\,(-,\xi,\mathscr{P}_f(\mathbb{N}))$$

The result of the interaction of $\mathfrak{D}$ with the fax $\mathscr{F}ax_{\xi,\xi'}$ consists in substituting ξ with ξ' in $\mathfrak{D}$, and that is all !

$$\dfrac{\dfrac{\overset{\mathfrak{D}_1}{\xi.1 \vdash} \quad \dots \quad \overset{\mathfrak{D}_n}{\xi.n \vdash}}{\vdash \xi}\,(+,\xi,I) \qquad \dfrac{\dots \quad \dfrac{\dots \quad \overset{\mathscr{F}ax_{\xi'.i,\xi.i}}{\xi'.i \vdash \xi.i} \quad \dots}{\vdash \xi.I, \xi'}\,(+,\xi',I) \quad \dots}{\xi \vdash \xi'}\,(-,\xi,\mathscr{P}_f(\mathbb{N}))}{}$$

After two steps, we get:

$$\dfrac{\overset{[[\mathfrak{D}_1, \mathscr{F}ax_{\xi'_1,\xi_1}]]}{\xi'.1 \vdash} \quad \dots \quad \overset{[[\mathfrak{D}_n, \mathscr{F}ax_{\xi'_n,\xi_n}]]}{\xi'.n \vdash}}{\vdash \xi'}\,(+,\xi',I)$$

The process follows in a recursive manner.

3. MODELING ARGUMENTATION DIALOGUES

Argumentation has been extensively studied with respect to the three following questions: what kind of argumentative schemas do we find in argumentative dialogues, how can we reason with arguments and compute the best strategy, or at least the next best move, for winning a controversy, how should contradictions that may arise during a dialogue be managed and how can a coherent solution to the debate be found? This last question is typically one of the judge's objectives during a juridical controversy.

With respect to the first question, game theory has been the model largely used since the 80's (see Walton (1985) for a survey of this period, Mackenzie (1990); Prakken (2008); Lascarides & Asher (2009); Prakken (2011); Ranalter (2012) for more recent works). It offers the means for modeling the various aspects of a confrontation between two locutors arguing for two opposite points of view. More concretely, the different methods for arguing and objecting to a proponent's argument are modeled as blocks of moves: a dialogue is a sequence of such blocks. Among them, one may sketch the following:[1]

- questioning the opponent is the easiest way to force her without revealing one's own arguments.
- arguing against what is said by the opponent is a more complex situation as it introduces new elements into the discussion, and at the same time the relation between counter-arguments and arguments must be logically sound.
- making use of presupposition is a way to force the opponent to accept a thesis without posing explicitly the proposition. We see below that such a case is easily dealt with in our model.
- making use of prolepsis consists in anticipating remarks or counter-arguments that may come from the opponent. Contrary to presuppositions, proleptic propositions are explicit. The opponent has the possibility to refute elements of such an intervention. One may consider the interventions of a judge in a juridical situation fit this case.

Reasoning and computing the best strategy for winning a controversy is a complex task as it requires being able to anticipate all possible counter-arguments, and finally to compare arguments in order to choose the more direct one. Concluding a controversy requires the ability to perform logical computation on the basis of the information that

comes to light during the dialogue. The approach widely taken consists in using a non-monotonic logics. For example, Prakken (2005) notices that "since argumentation typically involves defeasible reasoning, we need a nonmonotonic logic".

For our purpose, there is no need to consider a nonmonotonic logic. As a matter of fact, Linear Logic, and consequently Ludics, allows for erasing and adding elements in a monotonic logical framework. Furthermore, Ludics integrates in a single framework a game theoretical structure and an inferential system: interaction of designs is a kind of modus ponens and a travel through arguments. We sketch in this section how characteristics of argumentative dialogues may be represented in terms of *dialogue acts*, where a dialogue act is an elementary move as understood in Ludics. We model also inferences that may be performed given a player's commitment state and the current arguments posed in the dialogue. In the next section, we apply this to the case of a large example of a juridical dialogue.

3.1. Speech Acts versus Dialogue Acts

As proposed by Searle (1969), a *speech act* includes an utterance, its conditions as well as its effects. Furthermore, as mentioned by other researchers, it is also necessary to take into account extra-linguistic elements, as is the case in situations where one calls an object to somebody's attention with a gesture. This is why *communicational act*, or *dialogue act* is substituted for *speech act*. Landragin (2008) remarks that this notion of dialogue act is not precisely defined in the literature. He suggests defining a dialogue act as "the minimal unit of communication in a dialogical context", and to found the modeling of dialogues on that notion. This fits our own approach as an intervention is split up into elementary acts modeled as Ludics actions.

In most recent studies concerning speech acts, we note also that the principle of interaction is central. For example, it is the core of the approach of Ginzburg et al. (2003). By the way, revisiting the Speech Act assignment problem, Beyssade & Marandin (2006) remark that speech acts have to be considered with respect to the locutors' points of view. They posit that "illocutionary forces can be analyzed as conversational moves". In the same vein, our analysis considers a dialogue as an interaction with actions as primitive elements.

In our formalization of dialogues in Ludics, an intervention in a dialogue conveys one or several **dialogue acts**. A dialogue act is a communicational fact whose role is to provide the dynamics and determine the shape of the dialogue. It may be explicit or implicit, verbal or not (*e.g.* an acknowledgment given as a gesture). It may appear as one or more propositions, but also as part of a proposition (word, adverb, . . .). It expresses an entitlement or a decision of the speaker, and also its acknowledgment by the addressee. In some sense, it is quite close to a speech act. However a speech act may correspond to several dialogue acts as shown in example 7. Dialogue acts are indeed more elementary than speech acts. They can be seen as the basic blocks from which one builds interpretation of dialogical interventions or even utterances. Formally, a dialogue act is defined as an action in Ludics together with the expression that reveals the dialogue act in the intervention. Such an expression may be a proposition, a word (*e.g.* a single adverb, a noun), a prosodic feature, a non verbal sign (a nod, a shake, a slap, . . .). In trivial cases, an intervention is a unique dialogue act. Otherwise a turn of speech has to be decomposed into sequences of dialogue acts, hence may correspond to a complex design. Note that the representation of an utterance in terms of dialogue acts is dependent on the context of the dialogue, and in particular on interventions that have already occurred.

DEFINITION 1 (Dialogue Act). *A* dialogue act κ *is:*

- *either a proper dialogue act, that is to say a tuple* (ϵ, L, I, e) *where*
  - *the finite sequence of integers* L *is the* focus *of* κ*: the location of the act with respect to the dialogical interaction one considers,*
  - I *is the* ramification *of* κ*: the openings created by the dialogue act on which new dialogue acts may be produced,*
  - e *is the expression of the dialogue act, that is to say the language or communicational fact by means of which the dialogue act manifests itself,*

  - *the polarity* ϵ *of the act may be positive (+) or negative (−). The act is positive for the locutor that produces it except when this act is a constraint from its interlocutor (see below presupposition case). These acts have a dual polarity when received by the interlocutor.*
- *or a particular positive dialogue act, still called* daimon *and noted* $(\dagger, e)$*, that registers the end of an interaction that went well. In that case, the expression* e *of the dialogue act may often be empty.*

Example 6. *Consider the following variant of the dialogue between an examiner and Theo*

I_0	*Examiner*	*Do you want to speak?*
$I_0{}'$	*Theo*	*No.*
$I_1{}''$	*Examiner*	*Ok. Bye.*

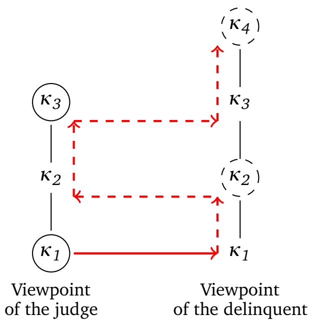
Each intervention is reduced to a unique dialogue act that we represent in the following way:

- $\kappa_0/\overline{\kappa_0} = (+/-, L, \{L_0\}, e_0)$ where e_0 is the proposition "Do you want to speak?"; L is a location arbitrarily chosen (since this act initiates the dialogue) in which the act occurs; this act creates only one continuation, the one on which Theo may anchor his answer.
- $\kappa_0{}'/\overline{\kappa_0{}'} = (+/-, L_0, \emptyset, e_0{}')$ where $e_0{}'$ is the proposition "No"; L_0 is the location of the act: this act is justified by κ_0; this act does not create new openings as it marks that Theo refuses the discussion.
- $\kappa_1{}'' = (\dagger, e_1{}'')$ where $e_1{}''$ is the expression "Bye"; with this dialogue act, the examiner informs Theo that the dialogue is finished.

The acts κ_0 and $\kappa_0{}'$ are positive from the point of view of the locutors that produce them: the examiner for the first, Theo for the second, they are negative for the locutors that receive them. The act $\kappa_1{}''$, positive, is produced by the examiner.

The following example is a standard case of dialogue with presupposition. A presupposition is an implicit assertion considered true within the discourse. It is a good example of the significance of decomposing interventions into elementary acts. The intervention of the locutor is a unique utterance but generates three dialogue acts, one of them is negative: it corresponds to an (implicit) intervention proposed to the interlocutor.

Example 7. *Let us consider the following well known example due to Aristotle; a judge asks a young delinquent this question: "Have you stopped beating your father?". Answering this question supposes that the answer to the implicit question 'Did you beat your father ?' is 'Yes':*
– *"Did you beat your father?"*
– *"Yes."*
– *"Have you stopped beating him?"*
The question asked by the judge, "*Have you stopped beating your father?*" displays three successive dialogue acts κ_1, κ_2 and κ_3 that refer respectively to interventions : "*Did you beat your father?*"; "*Yes*"; "*Have you stopped beating him?*". If the young delinquent continues the dialogue, he implicitly assumes that the interaction between the two (partial) designs does not diverge. Hence he accepts justifying his next intervention on the negative dialogue act corresponding to κ_3, this dialogue act being anchored on the positive dialogue act corresponding to κ_2: he assumes he would have answered "*Yes*" to the implicit question.



3.2. *First Elements for Modeling Dialogues*

A dialogue is modeled as an interaction between two *designs of dialogue* built incrementally from the interventions of the interlocutors, their turns of speech. A design of dialogue is a design in the sense of Ludics where the notion of action is replaced by the notion of a dialogue act. Constraints defining a design of dialogue are otherwise similar to what defines a design in Ludics. For ease of reading, we continue to speak of design in place of dialogue design. In this paper, we consider that, for

each dialogue, the two designs that serve for modeling the dialogue have the same initial locus. The first positive dialogue act, *i.e.* the dialogue act of the locutor who initiates the dialogue, is anchored on this locus. Correspondingly, the initial dialogue act of her addressee is negative and anchored also on this locus: this act models the fact that the addressee accepts the first intervention of the locutor.

With each intervention there is associated an alternate sequence of dialogue acts that complements the current design of the locutor. The result should still be a design. In particular, the first dialogue act of the intervention should be anchored in some previous intervention: indeed the dialogue is meaningful as soon as each intervention refers to an element previously discussed in the dialogue. Furthermore, the first and last dialogue acts of each intervention have to be positive: if the last action is not the daimon, the interlocutor may continue the dialogue. Dually, the design of the interlocutor is increased by what comes from the locutor, except when the dialogue diverges. The result should be such that one of the chronicles ends with a negative action: the interlocutor initiates her own intervention by a dialogue act anchored on this negative action.

The interaction between designs is similar to what it is in Ludics. At each step, it requires the presence of corresponding dialogue acts in the designs: the dialogue may continue if what a locutor utters is accepted by her interlocutor. Hence, after each intervention, if the previous requirement is not satisfied, the interaction diverges and the dialogue fails; if the interaction goes on to a daimon then the dialogue stops; otherwise, the dialogue resumes with the next intervention.

As we noticed in section 2, a dialogue being given, there is no need to limit designs to the dialogue acts that model the dialogue. In fact, designs may be "enlarged" by adding chronicles compatible with them[2]. With that in mind, argumentative schemas are conceivable as designs given *a priori*, *i.e.* before the dialogue takes place. This has been investigated in Lecomte & Quatrini (2011): each locutor has a *dialectal project* and the dialogue consists in letting them interact. Finally, the model we consider is obviously simplistic: in real conditions, natural language is ambiguous, non normalized, and interventions may be incorrectly understood. One way to tackle this problem may consist in analyzing a dialogue as a pair of interactions (instead of only one interaction). Let us suppose A dialogues with B, then A (resp. B) may have her own dialogue project P_A (resp. P_B), furthermore A (resp. B) interprets B's interventions (resp. A's interventions) as coming from a design P'_B (resp. P'_A). Hence two interactions take place: one between P_A and P'_B and the other between P_B and P'_A. There are differences as soon as interventions from one locutor are not "transparent" for the other locutor. However, even with differences, the dialogue may still converge ... or may diverge if a misunderstanding becomes clear.

3.3. *Argumentative Dialogues*

Argumentative dialogues show some peculiarities. In particular speech acts that compose them are of limited shape, mainly assertions, arguments, denial and concessions. In addition, a notion of win appears, which seems specific to argumentative dialogues. In a dialogue whose aim is to exchange information, to share knowledge or a feeling, the question of whether one of the speakers wins is quite irrelevant. But to know who is *right* after a controversy is essential. An argumentative dialogue is distinguished from (common) dialogues in the sense that two arguments are opposed, each party having her thesis to defend or advance. The dialogue is then mainly an exchange of arguments and counter-arguments with the sole purpose that the dialogue ends when a thesis is considered *winning*.

Inferring perspicuous arguments is one of the main reasons why argumentation is formalized in the framework of logics (*e.g.*Lascarides & Asher 2009). We should also mention a lot of studies that use game theories as theoretical framework (Walton 1985; Mackenzie 1990; Poesio & Mikheev 1998; Loui 1998; Prakken 2008, etc.). In game theory, two players try to win by applying precise rules. The domain of argumentative dialogues is similar: the dispute between two players ends with a win for one of the two. However, we notice two main differences between argumentative dialogues and games. First, the only rule that makes sense in the argumentative frame is the one relative to keeping the dialogue convergent: interventions should be relevant to the subject of the discussion. There are no other rules limiting the game. Second, in most games, each player makes only one elementary move. In the case of dialogues, one intervention may contain several speech acts, *e.g.* both concessions and counter-arguments.

In order to take care of argumentative dialogues, it is necessary to specify what is a "win" in our modeling. One of the locutors becomes a "loser" in one of two situations: she abandons the dispute conceding the last arguments, or she is obliged to do so by the other locutor (who becomes the winner): the winner has the last word. The second case is the standard one in juridical dialogues, where the judge may play in place of the locutors. Anyway, these two cases correspond to the end of a convergent interaction: a daimon is used and the locutor that uses it is the loser. We can specify the situations where a daimon is used: either the set of locations where an action may take place is empty, hence the daimon is the only possible action and the opponent really has "the last word", or there still exist locations where actions may take place and the locutor prefers to quit the dialogue. Note that winning is relative to a dialogue: it may be the case that the current loser may be a winner with another opponent. One defines a winning strategy, *i.e.* a winning design, when every interaction with such a design is either divergent or ends with a daimon in the opposite design. Such a design does not contain the daimon, and we should note that this a constraint for a design to represent a proof.

We consider below speech acts for argumentation proposed in Prakken (2008) and interpret them in terms of dialogue acts. In his paper, Prakken considers six elementary types of speech acts for argumentation. We use these schemas of interpretation in the next section to revisit the example of juridical dialogue given by Prakken and compare its proposal to ours.

- **To claim a thesis** (to affirm, to assert). This corresponds to posing a proposition in response to which the interlocutor may continue the dialogue by negating it or by conceding it or by asking for more explanations. Such a proposition may constitute the initial thesis of a dialogue, it may also be an additional element for an on-going discussion. In juridical situations, the proposition is unique. In other situations, a locutor may assert several propositions in the same intervention. In our Ludics framework, this is represented by a proper and positive dialogue act $(+, L, I, e)$, that may be initial or justified by one of the previous dialogue acts that introduces one of the subjects of the dialogue. In simple cases, *e.g.* juridical dialogues, the ramification I is a singleton.

- **To argue**. This corresponds to posing propositions that serve as argumentative premises and at the same time to articulating the relationship between these premises and the conclusion. For example, the locutor may affirm a thesis A and justify it with B and $B \Rightarrow A$, hence propositions that are posed are actions corresponding to the two elements B and $B \Rightarrow A$. This is the case in juridical dialogues when a locutor (or the judge) uses the law. This speech act is represented by a unique positive proper dialogue act $(+, L, I, e)$. Contrary to the previous item, the ramification I, hence the locations opened by this act, cannot be a singleton: it contains at least all the premises and the relation between the premises and the conclusion.

- **To negate** (to refuse). We consider this speech act as a kind of thesis, a claim of the locutor. However, such a claim cannot be an initial act of the dialogue: it is a refusal of a previous claim[3]. In a general setting, in such a turn of speech, the locutor may negate and pose a counter-argumentation by giving new facts. It is represented as a proper positive dialogue act $(+, L, I, e)$, necessarily justified by a previous act that introduces the proposition that is negated. The ramification I is a singleton in the juridical case, but may contain other elements in other cases.

- **To ask, to request some justification**. With respect to the structure of a dialogue, there is no difference between this and the previous item except the linguistic form it has.

- **To concede**. This consists in accepting one assertion that the interlocutor has made. Hence the dialogue will not continue on this element. As such, a concession is only a part of a turn of speech: either the dialogue ends with this (last) concession and the locutor abandons the dialogue, or the locutor continues her intervention on another element still under discussion. A sequence of two dialogue acts is associated with the concession: $(+, L, \{L_0\}, e_0), (-, L_0, \emptyset, e_1)$ where
  - the first one, positive, expresses what is conceded, its focus is the one created by the affirmation that one concedes and its ramification is a singleton,
  - the second dialogue act is a negative one, it is focused on L_0: the locus that the immediate previous act created, and it has an empty ramification. The effect is that the conceded affirmation disappears for the remainder of the dialogue.

- **To abandon**. This act ends the dialogue in a convergent way. The final intervention of a judge (the sentence) induces necessarily such an act. The positive dialogue act $(\dagger, e)$ fits exactly this situation. Its use finishes the interaction.

3.4. *Towards an Argumentation Framework*

The previous sections enabled us to define an argumentative dialogue as an interaction between two (dialogue) designs in which each intervention may be recognized as a sequence of speech acts, themselves being represented by a sequence of elementary dialogue acts. In ideal cases, *i.e.* when the interaction ends in a convergent way, the looser is the locutor who played the daimon.

In addition to the argumentative dialogue itself, in order to define a full argumentative framework, we have to give an account of the state of commitments for each locutor, which constitutes the context of the dialogue. We will give an account of these contextual elements by means of *commitment states*: one for each locutor. These commitment states are augmented during the process of dialogue as they integrate new elements arising from the dialogue. More precisely, we identify in this way the facts which are assumed publicly by each locutor. Furthermore, the extension and the updating of these commitment states are one of the main issues of the dialogue. This is taken into account by means of the dynamics of interaction.

A commitment state is a kind of knowledge base. Usually, a knowledge base is defined as a set of logical formulas: the propositions which are associated with the facts that the locutor assumes. Here this notion is slightly more refined. In Ludics the notion of logical formulas is replaced by the more general notion of behaviour, *i.e.* a closed set of designs with the same base. Here we generalize still further by including in a commitment state some sets of designs that are not necessarely closed. Even if we do not completely exploit this in this paper, it should give the opportunity of a fine-grained account of knowledges. Indeed, some knowledge is assumed as fully explicit propositions while other may be only partially assumed: one or several logical propositions may be associated with a given utterance without their full decompositions being known.

DEFINITION 2 (Commitment state).
A **commitment element** *(C.E.) is a set of designs with the same base. It is either associated with some factual proposition (a certain fact is assumed) and its base is positive, or it is associated with an inferential proposition (if something is valid then another thing is valid) and its base is negative.*

A **commitment state** *(C.S.) is a set of commitment elements* $\mathbb{B} = \{\mathbb{E}_1, \ldots, \mathbb{E}_i, \ldots\}$ *respectively based on* $\Gamma_i \vdash \Delta_i$.

Moreover the set $\mathbb{B}$ *is provided with some internal locative structure: suppose that* $\mathbb{E}_F$ *is a C.E. associated with the knowledge that F is the case while* $\mathbb{E}_{F\Rightarrow G}$ *is the knowledge that under the hypothesis F, G is the case, then the C.E.* $\mathbb{E}_F$ *and* $\mathbb{E}_{F\Rightarrow G}$ *are respectively based on* $\vdash L_F$ *and* $L_F \vdash L_G$ *(where* L_F *and* L_G *are loci for F and G).*

The commitment elements may be more or less elaborated.

The minimal account of a factual proposition '*F*' is a C.E. reduced to a unique design based on $\vdash L_F$. The minimal account of some inferential proposition '*F* implies *G*' is a C.E. reduced to a unique design based on $L_F \vdash L_G$.

We then represent an argumentative dialogue between two protagonists *S* and *A* in a way similar to Gazdar (1981); Ginzburg et al. (2003), Loui (1998) and others; that is, by a sequence of dialogue states. The specificity here is the definition of the dialogue state: it is a triple of data, the commitment state of *S* at this time, the commitment state of *A* at this time, and the net of two designs associated with the current dialogue at this time.

At each step, that is, after each intervention of one locutor, for example *S*[4], the situation evolves as follows:
- except for the first intervention of the dialogue, the design of *S* is increased by the sequence of the duals of the dialogue acts associated with *A*'s previous intervention, as *S answers* to *A* without diverging;
- the design of *S* is increased by the alternate sequence of dialogue acts

associated with her current intervention;
- the commitment state of *S* is updated according to the following principles: it is increased by the C.E. associated with the propositions assumed by the current intervention of *S* (the asserted propositions, the negated ones, the conceded ones). The C.E. which belong to the commitment state of *S* and on which *S* changed her mind are erased.

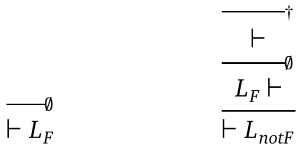
DEFINITION 3 (Argumentative situation).
A dialogue state *is a tuple* $(\mathbb{B}^i{}_S, \mathscr{D}^i{}_S, \mathbb{B}^i{}_A, \mathscr{D}^i{}_A)$ *where* $\mathbb{B}^i{}_A$ *and* $\mathbb{B}^i{}_S$ *are the commitment states of respectively A and S at step i of the dialogue and* $\mathscr{D}^i{}_A$ *and* $\mathscr{D}^i{}_S$ *are the respective designs of A and S at step i of the dialogue. The step* 0 *is before the intervention which starts the dialogue,* $\mathscr{D}^i{}_S$ *and* $\mathscr{D}^i{}_A$ *are empty and still considered as designs. Each intervention enables to go from step i to a next step* $i+1$*; we denote by* P_i *the locutor who produces the intervention from i to* $i+1$ *and* $\overline{P_i}$ *the other locutor.*
An argumentative situation *is a sequence of dialogue states such that:*

(1) $\mathbb{B}^{i+1}{}_{P_i}$ *is obtained from* $\mathbb{B}^i{}_{P_i}$ *by adding the C.E. corresponding to the propositions either asserted or conceded during the current intervention. The C.S. is updated by erasing designs that correspond to the affirmation of factual propositions while their negations are now conceded.*

(2) $\mathscr{D}^{i+1}{}_{P_i}$ *is obtained from* $\mathscr{D}^i{}_{P_i}$ *by adding:*
- the duals of sequences of dialogue acts corresponding to the immediate previous intervention from $\overline{P_i}$*. Indeed, since* P_i *continues the dialogue, she accepts the intervention of her addressee.*
- the sequence of dialogue acts corresponding to the current intervention performed by P_i.

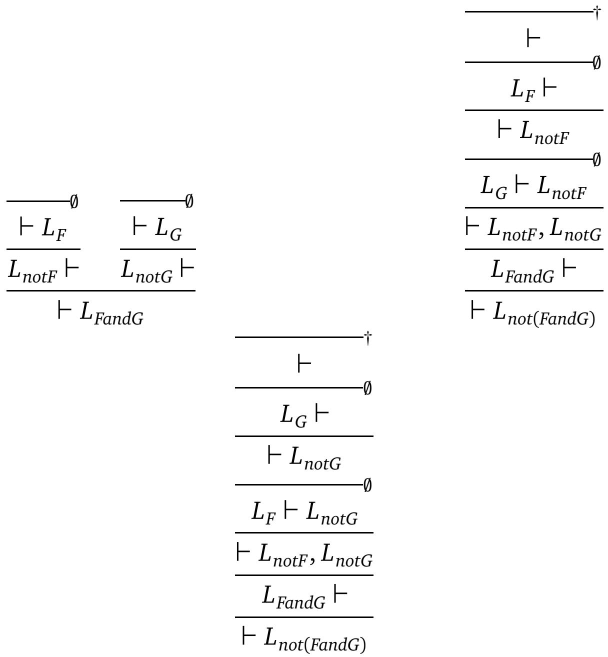
The management of the commitment states, their updating and their utilization in the dialogue in progress make use of properties and notions of Ludics that we discuss below:

- **Negation.** We distinguish between a positive factual proposition: *something is the case* and a negative factual proposition: *something is not the case*. The C.E. associated with the negative factual proposition is the design which expressed the logical negation of the positive one. More precisely, the following designs are respectively associated with the factual propositions '*F is the case*' and ‘*F is not the case*’, when F is an *atomic* factual proposition (L_F is the location of F, L_{notF} is the location of *not* F):



Factual propositions that are logically decomposable may also be represented as C.E. In such cases the designs start with actions corresponding to the adequate logical decomposition. We give below the example of a conjunctive factual proposition.

The following designs are respectively associated with the factual propositions: ‘*the conjunction of F and G is the case*’ (located at $L_{\mathtt{FandG}}$) and ‘*the conjunction of F and G is not the case*’ (located at $L_{not(FandG)}$):



REMARKS :

(1) Loci are indexed by their intuitive interpretation. These addresses should not be confused with the logical notation of propositions.

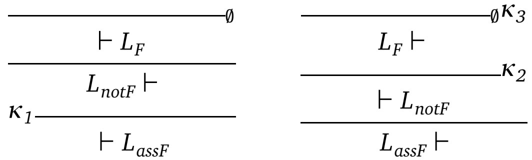
(2) For a stricly commutative treatment of conjunction, we need both designs in the right in the C.E. associated with *the conjunction of F and G is not the case*.

- **Delocation.** In Ludics the more primitive notion is that of *location*.

  In our modeling, location is also fundamental.

  When a proposition appears in some dialogue act, the locus of the dialogue on which this proposition is anchored has to be seen as a delocation of the locus on which this proposition is stored in the C.S. Such a delocation is obtained by using a *fax* design, presented in subsection 2.3. We do not insist on this point here. Nevertheless we may notice that this is very useful for describing how some information is transmitted.

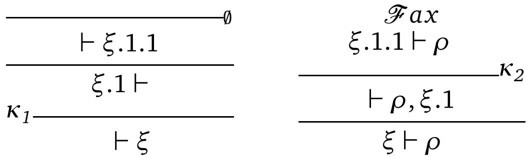
  Consider, for example, the following situation: a speaker asserts a factual proposition F which is conceded by her addressee. Using our modeling of dialogue, we represent this situation by the following interaction:



The dialogue seen from S — The dialogue seen from A

The dialogue act κ_1 is the assertion of F by S.
The sequence of dialogue acts $\kappa_2\kappa_3$ is the concession of F by A.

Indeed, the dialogue occurs on loci, say ξ, $\xi.1$, $\xi.1.1$, instead of L_{assF}, L_{notF} and L_F. The design above $\xi.1.1$ is in fact obtained from a delocation of the C.E. associated with the proposition F in the C.S. of S. Moreover, a complete account of the concession has to give an account of the appropriation by the addressee A of the proposition F. This is possible if we represent the concession by a $\mathscr{F}ax$ delocating $\xi.1.1$ to ρ. In the figure above representing the dialogue we retained only the useful interacting part of it. The full situation is as follows:



The dialogue seen from S The dialogue seen from A

The resulting design of this interaction is the C.E. associated with the factual proposition F stored by A. We give an account of the transmission of the factual proposition '*F is the case*' by a succession of delocations of this proposition: from the locus L_F which is the locus on which the proposition is anchored in the commitment state of the speaker S to the locus $\xi.1.1$ which is the locus of the dialogue on which the proposition is anchored. And then from $\xi.1.1$ to ρ, the locus on which the proposition is anchored in the commitment state of the addressee A.

- **Interaction.** In a C.S. the designs may interact with each other. Moreover all possible logical combinations between them are possible provided that adequate delocations are used. The normal forms resulting from their interactions belong also to the C.S.

In order to illustrate the effect of an intervention during an argumentative dialogue, we give below an example which is developed in the next section.

Example 8. *A juridical controversy between a plaintiff P and a defendant D starts as follows:*

I_1	*Plaintiff:*	I claim that defendant owes me 500 euro.
I_2	*Defendant:*	I dispute plaintiff's claim.
I_3	*Plaintiff:*	Defendant owes me 500 euro by r_1 since we concluded a valid sales contract, I delivered but defendant did not pay.

To start, we focus on the argumentative dialogue. According to our modeling, the two first interventions I_1 and I_2 each create only one new locus, respectively L_1 and L_2. On the contrary, the intervention L_3 is represented by a dialogue act which creates four new loci. Indeed the utterance I_3 '*Defendant owes me 500 euro by r_1 since we concluded a valid sales contract, I delivered but defendant did not pay*' makes explicit four argumentative elements to support his assertion '*Defendant owes me 500 euro*'. These argumentative elements are: a law article r_1; the fact that both parties concluded a valid contract; the fact that plaintiff delivered his service and, finally, the fact that defendant did not pay 500 euros. By means of this dialogue act, we indicate that the dialogue may continue using loci $L_{3_1}, \ldots, L_{3_4}$ respectively associated with these four elements.

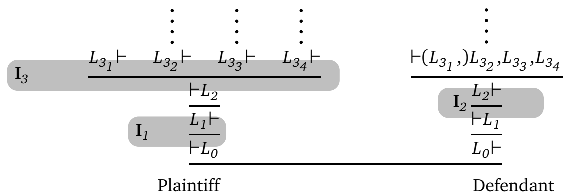


Figure 1: A juridical example: Interventions I_1 to I_3

Let us detail how we interpret this intervention with respect to the commitment state of plaintiff P. Plaintiff gives several pieces of information: *there is a valid contract between P and D*, *P delivered*, and *P* applies the law r_1, the implicit content of r_1 is *If there is a valid sales contract between a vendor and an emptor and if the vendor delivers then the emptor has to pay'*.

The following C.E. are added to the commitment state of P by this third intervention:

- The design associated with the law r_1 is based on $L_{Cont-and-Del} \vdash L_{to.pay}$. This is a rather elaborated design:

$$\mathcal{D}_{r_1} = \dfrac{\dfrac{\dfrac{\dfrac{\dfrac{\dfrac{}{\vdash L_{to.pay}}{\scriptstyle \emptyset}}{L_{Del} \vdash, L_{to.pay}}{\scriptstyle \emptyset}}{\vdash L_{notDel}, L_{to.pay}}}{L_{Cont} \vdash L_{notDel}, L_{to.pay}}{\scriptstyle \emptyset}}{\vdash L_{notCont}, L_{notDel}, L_{to.pay}}}{L_{Cont-and-Del} \vdash L_{to.pay}}$$

- The designs respectively associated with the assertions '*there is a valid contract between P and D*' and '*P delivered*' are the following:

$$\mathcal{D}_{cont} = \dfrac{}{\vdash L_{Cont}}{\scriptstyle \emptyset} \qquad \mathcal{D}_{del} = \dfrac{}{\vdash L_{Del}}{\scriptstyle \emptyset}$$

- There is also in the C.S. of P the following design associated with the fact that defendant did not pay (interpretation of intervention I_1):

$$\mathcal{D}_{not.paid} = \dfrac{\dfrac{\dfrac{}{\vdash}{\scriptstyle \dagger}}{L_{to.pay} \vdash}{\scriptstyle \emptyset}}{\vdash L_{notPay}}$$

The loci $L_{3_1}, \ldots, L_{3_4}$ respectively associated with the argumentative elements in the intervention I_3 are delocations of the loci on which the four designs $\mathcal{D}_{r_1}$, $\mathcal{D}_{cont}$, $\mathcal{D}_{del}$ and $\mathcal{D}_{not.paid}$ are anchored. A computation using these designs yields a contradiction: indeed, the result of the interaction between designs $\mathcal{D}_{cont}$, $\mathcal{D}_{del}$ and $\mathcal{D}_{r_1}$ (by using additional logical steps) is the following design:

$$\mathcal{D}_{to.pay} = \dfrac{}{\vdash L_{to.pay}}{\scriptstyle \emptyset}$$

Then the interaction between this latter design and $\mathcal{D}_{not.paid}$ results in a logical contradiction. The subsequent dialogue consists of giving arguments until the contradiction may be solved.

4. A JURIDICAL CONTROVERSY

A juridical controversy is an argumentative dialogue between three protagonists among whom someone plays a special role: the judge has to allocate the burden of proof and has to evaluate the argumentation in order to formulate a sentence. However, we propose to account for legal controversies as if the dialogue concerns only the defendant and plaintiff: each intervention of the judge is represented as an intervention from one of the two parties. After each such intervention, the turn of speech is to the other party. In this way we model the distribution of the burden of proof by the judge: she imposes concessions, she validates assertions, and when she gives the turn of speech to the other protagonist, she implicitly asks for additional elements. Moreover, the sequence of dialogue acts associated with the last intervention of the judge, *i.e.* the sentence, enables her to close the pending branches in the dialogue designs, in such a way that the protagonist that has the turn of speech has no more available locus in his design: he is obliged to play the daimon, hence becomes the loser.

In this section we consider an example of a juridical controversy. This example is due to Prakken who introduced and studied it (Prakken 2008).

Example 9. *The following juridical dialogue takes place between plaintiff (P) and defendant (D).*

I_1	*Plaintiff:*	I claim that defendant owes me 500 euro.
I_2	*Defendant:*	I dispute plaintiff's claim.
I_3	*Plaintiff:*	Defendant owes me 500 euro by r_1 since we concluded a valid sales contract, I delivered but defendant did not pay.
I_4	*Defendant:*	I concede that plaintiff delivered and I did not pay, but I dispute that we have a valid contract.
I_5	*Plaintiff:*	We have a valid contract by r_2 since this document is a contract signed by us.
I_6	*Defendant:*	I dispute that this is my signature.
I_7	*Plaintiff:*	Why?
J_1	*Judge:*	By r_3 the party who invokes a signature under a document which is not an avidavit has the burden to prove that it is authentic when this is disputed, so plaintiff must prove this is defendant's signature.
I_8	*Plaintiff:*	This is defendant's signature since it looks like these three signatures of which we know they are defendant's.
I_9	*Defendant:*	But it does not look like this signature, which is also mine. Besides, another reason why we have no contract is that I was insane when I agreed, so r_4 applies, which makes section r_2 inapplicable.
I_{10}	*Plaintiff:*	I dispute that you were insane.
I_{11}	*Defendant:*	My insanity is proven by this court's document, which declares me insane.
I_{12}	*Plaintiff:*	I dispute that this is a court's document.
J_2	*Judge:*	Plaintiff, since this document looks like a court's document, i.e. like an affidavit, by r_5 the burden is on you to prove that it is not.
I_{13}	*Plaintiff:*	This lab report proves that this document is forged.
J_3	*Judge:*	This document is inadmissible as evidence by r_6 since I received it after the written pleading phase.
I_{14}	*Plaintiff:*	Nevermind, even if defendant was insane, this could not be known to me during the negotiations, so r_4 does not apply by r_7.
I_{15}	*Defendant:*	Why could my insanity not be known to you ?
I_{16}	*Plaintiff:*	Since you looked normal all the time.
J_4	*Judge (deciding the dispute):*	I am conviced by plaintiff's evidence that defendant's signature under the contract is authentic. Yet I cannot grant plaintiff's claim since the fact that defendant looked normal during the negotiations is insufficient to conclude that defendant's insanity could not be known to plaintiff: he might have known if he had checked the court's register. Therefore I deny plaintiff his claim.

For easiness of reading of the presentation, loci are denoted by labels L_i (when they are produced by an intervention I_i of plaintiff or defendant) and J_j (when they are produced by an intervention J_j of the judge), L_0 is an arbitrarily chosen locus on which the exchange starts. We add sub-indexes to distinguish loci created by the same intervention (for example intervention I_3 is interpreted by a dialogue act with a ramification containing four elements, we denote it: $(+, L_2, \{L_{3_1}, L_{3_2}, L_{3_3}, L_{3_4}\}, e)$ where e is the full utterance constituting

intervention I_3. In figures given in this section, an intervention is depicted as a shaded area.

4.1. *Interventions I_1 to I_4*

The three first interventions were studied in example 8. Intervention I_4 is more complex, it is not made available by a unique dialogue act but by a sequence of several. Indeed, in intervention I_4, defendant concedes two plaintiff's elements: '*plaintiff delivered*' and '*I did not pay*'. These two concessions are successively represented, each of them being a positive dialogue act followed by a negative one with an empty ramification, at first above L_{3_4} then above L_{3_3}. At last intervention I_4 ends by negating the factual proposition '*The parties concluded a valid sales contract*', this is represented as a positive dialogue act focused on L_{3_2} and with a singleton as ramification. The argumentative dialogue until this fourth intervention is represented in figure 2. After this fourth intervention, the commitment state of D, CS_D, is increased with two designs: $\mathscr{D}_{del}$ and $\mathscr{D}_{not.pay}$, that are delocated from the commitment state of P, CS_P (these designs are described in example 8).

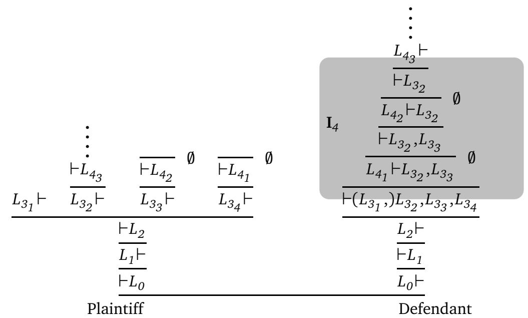


Figure 2: A juridical example: Intervention I_4

4.2. *Interventions I_5 to J_1*

The three following interventions, I_5, I_6, I_7, are modeled in a similar way. The judge's intervention J_1 introduces the application of a rule (r_3), a non-debatable premise ('*the document is not an avidavit*'), and the obligation for plaintiff to prove the validity of the signature. In the interaction associated with the argumentative dialogue between plaintiff and defendant, it appears as if it were an intervention of defendant. Its effect is to give the turn to plaintiff. This is represented in figure 3.

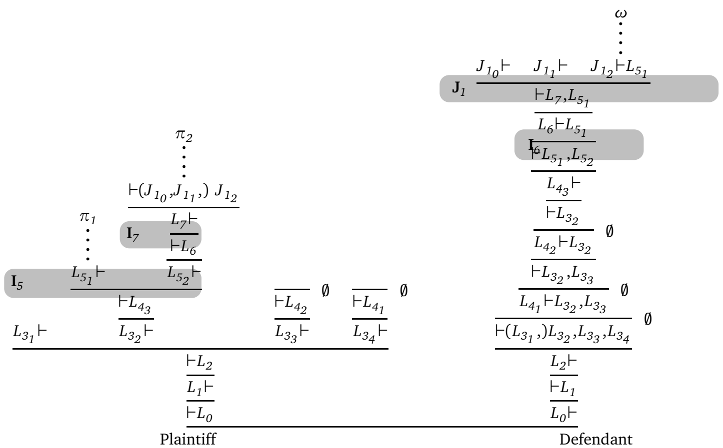


Figure 3: A juridical example: Interventions I_5 to I_7 and J_1

Both commitment states CS_D and CS_P are extended with designs associated with rule r_3 and the factual proposition '*the document is not an avidavit*'. At this step we find also in CS_P a design associated with the factual proposition '*The signature on the contract is valid*' while there is in CS_D a design associated with the factual proposition '*The signature on the contract is* **not** *valid*'.

4.3. *Interventions I_8 to I_{16} and J_4*

The dialogue continues accordingly. However two elements deserve attention: intervention I_9 and the judge's conclusion J_4.

By his intervention I_9, defendant, at first, counter-argues about the validity of the signature without letting the plaintiff answer. On the contrary, he continues by introducing a new counter-argument. The passage between these two different stages is expressed by '*Besides*'. So, the defendant's intervention I_9 is composed by a sequence of dialogue acts:

- the first one is positive: $(+, L_8, L_{9_1}, nosign)$ and it is expressed by '*But it does not look like this signature, which is also mine*'.

- the second one is negative: $(-, L_{9_1}, L_{9_1}', B)$, and expressed by B='*Besides, another reason why we have no contract*'. Defendant keeps the turn of speech and in this way he deprives plaintiff of the opportunity to answer. Nevertheless, a positive locus L_{9_2} still remains in his design: it is still available to him to argue that the signature is not valid.

- at last the third dialogue act is positive: $(+, L_{5_1}, \{L_{9_2}, L_{9_3}\}, noval)$. It is focused on the locus L_{5_1} that a previous dialogue act created (use of rule r_2 in intervention I_5). The third dialogue act creates two loci: L_{9_2} and L_{9_3} on which the discussion may continue, either about rule r_4 or about defendant's illness. This third dialogue act is expressed by '*I was insane when I agreed so r_4 applies, which make section r_2 inapplicable*'.

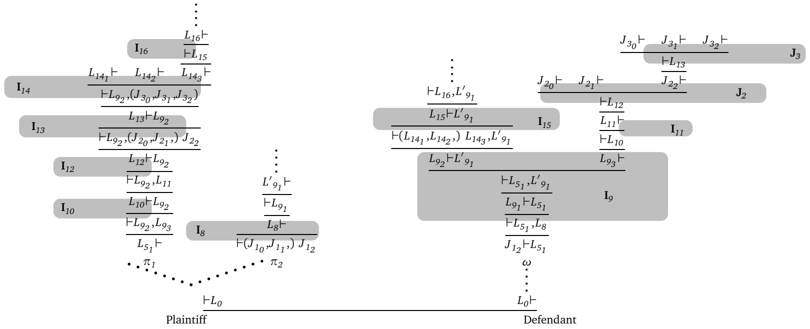


Figure 4: A juridical example: Interventions I_8 to I_{16}

After intervention I_9, two new elements are included in CS_D: the design associated with the factual proposition ‘*Defendant was insane during the contract’s signature*’, and the one associated with the inferential proposition ‘*Defendant’s insanity implies that r_2 is inapplicable*’ which is an application of law r_4.

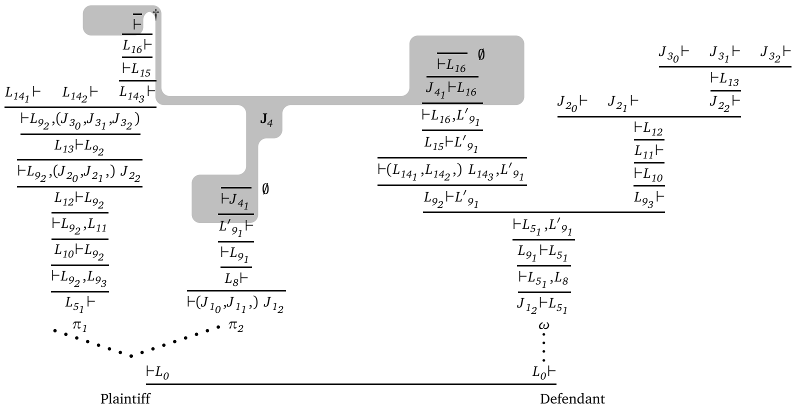


Figure 5: A juridical example: Intervention J_4

The judge formulates her sentence when the situation is as follows: the only avalaible loci are L_{16} and L'_{9_1}, potential foci for defendant’s interventions.

Indeed, loci associated with laws or with factual propositions asserted by the judge cannot be discussed in the dialogue. These loci are *weakened* in the model[5]. Locus L'_{9_1} is a pending locus, it concerns the validity of the signature. About that point the judge gives right to plaintiff, she imposes a concession to defendant, that is the succession: $(+, L_{9_1}', J_{4_1}, valsig?)(-, J_{4_1}, \emptyset, valsig)$ in the design of defendant (and also the dual in plaintiff’s design).

Locus L_{16} refers to defendant’s insanity. About that point, the judge gives right to defendant, the corresponding dialogue act is $(+, L_{16}, \emptyset, normal)$ in defendant’s design and $(-, L_{16}, \emptyset, normal)$ in plaintiff’s design (a concession). So, it is now the plaintiff’s turn of speech, he has no more avalaible loci, he is obliged to play the daimon. His claim is set aside.

We may also check the situation of the commitment states. Accepting defendant’s illness, the judge imposes that CS_D as well as CS_P integrate the design associated with this fact. Moreover, the design associated with the law r_4 necessarily belongs to the two commitment states. The result of the interaction between these two designs is the one corresponding to the fact that r_2 is not applicable. The design $\mathscr{D}_{to.pay}$ is then no more derivable and the contradiction disappears.

4.4. Remarks about the modeling

Let us outline the main points of our modeling, by means of which a complete formalization of Prakken’s example was realized.

In the interaction which constitutes the argumentative dialogue, the judge intervenes in place of one or the other party. Her interventions *impose* dialogue acts corresponding either to concessions or to requests for further information. In the latter case, this is underlined by the fact that the judge gives the turn to the party that has the burden of proof. The judge’s last intervention closes the dialogue and makes explicit the judgement. This last intervention ends still pending branches, either by means of empty ramification or by means of a final dialogue act: the daimon. The conclusion derives from the way concessions are imposed. The last negative act with an empty ramification is in the design of the party who now has the turn of speech: this establishes the party who is obliged to play the daimon.

Even though the controversy is represented as an interaction between two designs, the commitment states give the way the argumentative elements are articulated; computation *inside* each commitment state gives an account of the respective positions of the different protagonists. So, at the beginning, the argumentative elements given by plaintiff justify (according to him) his claim. Once formalized in the commitment state of P, the designs associated with these elements yield by interaction to a contradiction which sums up the claim: something needs to be *repaired* in order to eliminate this contradiction. The judge validates or invalidates arguments, that is to say designs in commitment states, to solve the contradiction that may result from the interaction between them. This is indeed what she does when she formulates the sentence. Either the judge invalidates the illness argument, in which case rule r_2 applies and also its logical consequences, which justifies plaintiff's claim and needs a judge's intervention: she imposes the design $\mathscr{D}_{to.pay}$ for the defendant, or she adds the design $\mathscr{D}_{illness}$ to the commitment state of the plaintiff, in which case nothing has to change for the defendant's state, in particular neither the premises of r_2 nor its conclusions are in it.

5. CONCLUSION

In the previous sections, we presented Ludics and the way it may be used for modeling argumentative dialogues. It should be clear that this is an ongoing research that changes largely standard approaches to argumentation, as Ludics changes radically the point of view we may have on logics. In Ludics, the fundamental operation concerns interaction between objects called designs. Such objects may clearly be interpreted in a certain sense as "proofs". However, two main differences exist with what is generally called a proof that should be considered. First, a design may include daimon actions, this allows for considering proofs and counter-proofs in the same language. Second, a design may be infinite (in depth as well as height), hence such an object may include enough information to interact with an infinite number of counter-objects. We recall also that Ludics is a rebuilding of Linear

Logic: formulas may be denoted by closed sets of designs. In that way, one recovers standard concepts of logics, say truth, proof, etc.

If we summarize our modeling of argumentation by means of Ludics, the dialogue is conceived as an interaction between two designs, one for each locutor. Moreover, each interaction gives rise to facts, either arguments, concessions, and so on, that are modeled also as designs in the commitment state of the locutor. Computations with such pieces of information is also done with the operation of interaction. The modeling of the juridical example we considered in the last section follows these principles. Moreover we showed how the interventions of a judge (and more importantly her sentence) are interpreted as interventions forced for one or the other party. This approach needs to be carried on to improve the propositions and to tackle in an extensive way other questions relevant for argumentation modeling.

Notes

[1]The reader may find in Walton (2012) definitions for standard terms in use, say rebuttal, refutation, proleptic argumentation.

[2] "compatible" means that what is obtained is still a design.

[3]Note that an initial claim may also be a negation. There is a difference between beginning a dialogue with, *e.g.*, "Paul did not come yesterday" and saying "You are wrong. Paul did not come." as a reply to "Paul came to the party yesterday."

[4]The situation is perfectly symmetrical between S and A.

[5]In figures, weakened loci are put in parentheses.

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