

Dialogue and game theory

Jean Caelen, Anne Xuereb
LIG, UMR5217, Domaine universitaire, BP 53
38041 Grenoble Cedex 9
{Jean.Caelen, Anne.Xuereb}@imag.fr

Abstract— The game theory is an interesting framework for the dialogue modeling, both the human dialogue and the human-machine dialogue. Indeed, the dialogue comes as a series of turn talking oriented towards achieving a goal. Each turn is composed by speech acts – can be likened to "moves" of game theory – which produces the effects of gains or losses during the dialogue. The main advantage concerning the application of the game theory in dialogue is that it does not require knowledge of cognitive processes or intentions of the participants, but assumes only that they have issues and interests in the dialogue they seek to satisfy. This article describes our contribution on the pragmatics of the dialogue: (a) the dialogue is not only a cognitive processing and relevant statements of the utterances produced by the other (the alter-ego) nor a social game using domination through a more or less logical argument to reach its goals or rhetorical means to achieve his ends, but also (b) a co-construction of self through gains advancing its own goals. In this paper we consider dialogue as a double process around the choice of ends and the means. Finally, we propose a general model of dialogue based on game theory.

Dialogue ; game theory ; pragmatics

I. INTRODUCTION AND THEORIC POSITIONING

The dialogue is a goal oriented process, submitted to a joint action [1] and an interactive process, where language is both the aim and the mean, between human agents evolving in a socio-economic world. In this context, the game theory provides interesting tools to model interactive situations where people have to achieve goals within an economy of means.

In this paper we will consider the game theory with the objective of applies it to dialog modeling. The similarities between dialogue and Game Theory rely on the following aspects of interaction:

(a) Human dialogue takes place simultaneously on different levels:

- At the level of action (the resolution of the goal) ; this level concerns the speech acts that are exchanged during the dialog, (speech acts correspond to « moves » in game theory),
- At the epistemic level (knowledge acquired and shared during the dialogue, discourse references, context, etc.) which will eventually provide to each partner immaterial payoffs (under the form of increasing of knowledge),

- At the deontic level through the rules of the game, influences and reciprocal rights, trust, etc. to providing a joint gain. It measures the joint acquisitions during the dialogue, like the trust, the value of alliance or coalition
- The “phatic” level or dialog maintaining, through the management of turns, the communication channel).

(b) it occurs often within the same framework for regular dialogue (family, work, etc..) inducing successive sessions of dialogue that we will consider as repeated games - this is the weak point of most dialogue theories that isolate a fragment of dialogue out of its everyday context, and thus mask the long term contextual effects due to the repetition,

(c) it usually happens between several people and not between two persons only, which induces more complex collective phenomena.

The dialogue can be represented by an interactive game where each participant plays moves using speech acts to achieve a goal. It consists of a sequence of turns, the exchanges aims at solving sub-goals or preconditions acts (named preparatory conditions)

Note that in terms of classical game theory it is only the epistemic, ontological and acting levels which measure valuables gains, while the deontic one provides only advantages. We will show later how to introduce a measure of these advantages and take them into account for the dialogue through the joint gain.

Using game theory to model the dialogue is to assume that the agents have both an individual interest and a joint interest in the continuation of the dialogue. These interests are measured by an utility value - a term taken in the broadest sense possible, as discussed below. The game theory is interesting because it don't attempt to explain or interpret the psychological behavior of participants in the dialogue, nor to make assumptions about their intentions, always uncertain in an external view of dialogue description.

At first, we present the foundation of game theory and then we will develop a model of dialogue based on a extended theory.

II. THE GAME THEORY

In mathematics, game theory models strategic situations, or games, where individual's success in making choices depends on the choices of others. It is used in social science (most notably in economics [2], but also political science, social psychology) as well as in biology. We will discuss below some types of games, not to bring the dialogue to the theory of games as some authors are tempted to do [3] but rather to use elements of game theory to model the dialogue in an extended vision.

A. Strategic game

In a strategic game, the gain of the player is not only affected by his actions, but also by the actions of other players. A strategic game is a set of rules which governs or constrains the behavior of the players. This set of rules determines the payoffs on the basis of the actions that occur. A strategic game consists of:

- a set of rules : that restrains the players' behavior,
- a set of payoffs for each player. The utility function defines the value of the payoff for each combination of choices,
- a strategy, i.e a choice among all possible moves. It instructs the player which action to take every time he has to play.

The players play a game, and they make moves according to the rules. Each player makes his move by choosing among several possibilities: he freely applies an own strategy.

It is assumed that the agents are rational, they know perfectly what is happen in the game, and that they act so as to maximize their utility. Their strategy is based on self-interest: they have to be aware of this and to be able to compute it through the effects of their actions.

The limits of this formalization are related to the concept of rationality on the one hand - the cognitive abilities of the players are actually limited or reduced, it is impossible to treat all needed information for the decision-making, in some complex situations human agents don't have the complete nor certain knowledge ; in addition, the rationality of the actor is procedural: the decision making does not imply to select the optimal choice (computation is too complex) but rather to select a satisfying choice - and the concept of collective interest of the other: the concept of interest is often too simplistic in decision models, it is individual and should be expanded to take into account concepts such as fairness, self esteem, ethics and culture.

The "neoclassical" game theory assumes that the agents are rational and self-interested, and they take care about their own interest only, or about the gains of the others, if they affect their own gains. But this behavior has to be reviewed, because it is shown that the feeling of fair sharing, or fair price can be taken in account. Humanitarian values come into consideration in some situations ; for example in bargaining context, the customer may accept a price that is higher than

the equilibrium if he seems to him that the seller makes a high concession [4], or he do not want to make more effort in the discussion.

There is also the Allais 'paradox, which highlights the risk aversion [5]: an agent will prefer a strategy apparently safer but with a lower low gain rather than a search for strongest gain with a greater risk. We could list some others examples of this.

B. Types of game

According to the situation, the game theory offers different types of games, that we describe here briefly.

1) Cooperative game / Non-cooperative game

A game is *cooperative* if the players are able to form binding commitments

2) Zero-sum game / non-zero-sum game

In a zero-sum game, a participant's gain or loss is exactly balanced by the losses or gains of the other participant(s). If the total gains of the participants are added up, and the total losses are subtracted, they will sum to zero.

3) Perfect information / imperfect information

A game is one of perfect information if all players know the moves previously made by all other players. Thus, only sequential games can be games of perfect information, since in simultaneous games not every player knows the actions of the others.

4) Complete information / incomplete information

Complete information requires that every player know the strategies and payoffs of the other players; otherwise the information is said incomplete.

5) Repeated games

Games are often played with *future* games in mind, and this can significantly alter their outcomes and equilibrium strategies. A repeated game consists in some repetitions of a base game (called the stage game) over a long time horizon. As players expect to face each other in similar situation, they may reduce their payoffs in a stage game, in order to increase it later.

C. Summary

All these types of games provide an interesting framework for dialogue modeling. The ordinary dialogue is a game with perfect information: the agents are visibly facing each other, even if one of them is trying to lie or to hide his strategy. The agents makes their moves (speech acts) alternatively, one after each other. Because of the epistemic and deontic level (mentioned in introduction of this paper), the dialogue is a game with incomplete information: we cannot access to the intention of other agent, nor the totality of his motivations. When people know each other and their dialogues occur in similar situations, it is a case of repeated game that is very different as a unique dialogue.

D. Central concepts in Game Theory

Nash Equilibrium

A “Nash equilibrium”, named after John Nash, is a set of strategies, one for each player, such that no player has incentive to unilaterally change her action. Players are in equilibrium if a change in strategies by any one of them would lead that player to earn less than if she remained with her current strategy.

Strategic dominance

Strategic dominance (commonly called simply dominance) occurs when one strategy is better than another strategy for one player, no matter how that player's opponents may play. Strictly dominated strategies cannot be a part of a “Nash equilibrium”, and as such, it is irrational for any player to play them.

The Prisoner's Dilemma and Pareto Efficiency

This game got its name from the following hypothetical situation: imagine two criminals arrested under the suspicion of having committed a crime together. However, the policemen do not have sufficient proof in order to have them convicted. The two prisoners are isolated from each other, and the policemen visit each of them and offer a deal: the one who offers evidence against the other one will be freed. If none of them accepts the offer, they are in fact cooperating against the police, and both of them will get only a small punishment because of lack of proof (1 year). They both gain. However, if one of them betrays the other one, by confessing to the police, the defector will gain more, since he is freed; the one who remained silent, on the other hand, will receive the full punishment (5 years), since he did not help the police, and there is sufficient proof. If both betray, both will be punished (3 years). The situation is described by the matrix below.

		S2	
		Denounce (defect)	Keep quiet (cooperate)
S1	Denounce (defect)	(3 ; 3)	(0 ; 5)
	Keep quiet (cooperate)	(5 ; 0)	(1 ; 1)

Each player evaluates his two possible actions here by comparing their personal payoffs in each column, since this shows you which of their actions is preferable, just to themselves, for each possible action by their partner. So, observe: if S2 denounces then S1 get a better utility in denouncing (3 years instead of 5). If S2 keeps quiet then S1 get a better utility by denouncing (free instead of 1). Therefore, S1 is better off denouncing regardless of what S2 does. S2, meanwhile, evaluates his actions by comparing his payoffs down each row, and he comes to exactly the same conclusion that S1 I does. The unique equilibrium for this game is a Pareto-suboptimal solution, that is, rational choice

leads the two players to both play defect, even though each player's individual reward would be greater if they both played cooperatively (keep quiet). In the classic form of this game, cooperating is strictly dominated by defecting, so that the only possible equilibrium for the game is for all players to defect. No matter what the other player does, one player will always gain a greater payoff by playing defect. Since in any situation playing defect is more beneficial than cooperating, all rational players will play defect, all things being equal. Although they are not permitted to communicate, if the prisoners trust each other then they can both rationally choose to remain silent, lessening the penalty for both of them.

Such a distribution of losses and gains seems natural for many situations, since the cooperator whose action is not returned will lose resources to the defector, without either of them being able to collect the additional gain coming from the "synergy" of their cooperation.

One must take in account social norms, culture, education, trust, etc. in order to model situations in the real life.

The iterated prisoner's dilemma

If two players play prisoner's dilemma more than once in succession and they remember previous actions of their opponent and change their strategy accordingly, the game is called iterated prisoner's dilemma. Interest in the iterated prisoner's dilemma was kindled by Robert Axelrod [6]. In it he reports on a tournament he organized of the N step prisoner dilemma (with N fixed) in which participants have to choose their mutual strategy again and again, and have memory of their previous encounters. Axelrod invited academic colleagues all over the world to devise computer strategies to compete in an IPD tournament. The programs that were entered varied widely in algorithmic complexity, initial hostility, capacity for forgiveness, and so forth. Axelrod discovered that when these encounters were repeated over a long period of time with many players, each with different strategies, greedy strategies tended to do very poorly in the long run while more altruistic strategies did better, as judged purely by self-interest. He used this to show a possible mechanism for the evolution of altruistic behavior from mechanisms that are initially purely selfish, by natural selection.

III. GOALS AND STRATEGIES OF DIALOGUE

After this reminder of game theory, the dialogue can be seen as a conversational game within an action framework [7]. The speakers contribute to the dialogue game with the joint intention to achieve goals. One must distinguish between the goal of the dialogue, that is in the background from the conversational goal that is necessarily shared (if it is not, there is a misunderstanding about the type of dialogue), and the goals (or interests) of the speakers. The strategies of dialogue are ways to reach a dialogue goal through the dialogue seen as a joint activity of goal's agents resolving [8].

We suppose that there are two agents who enter into dialogue and that at the start each one aims at a certain goal in the background. We will note S for speaker and H for hearer

Their goals will be noted, b_S and b_H , one of them possibly being empty. Let us define:

Initial goal: The state of the world or the mental state that one of the two speakers wants to reach, either for himself (to obtain an information, acquire a know-how, etc.), or for his partner (give him an information, make him do something, give him a piece of advice, etc.).

Conversational goal: the finality of the conversation: convince, make decisions, actions to carry out in common, negotiation, etc.

Exchange: a series of talking turns during which a goal is sustained. The start of an exchange is marked by the emergence of a new goal, this goal is possibly transformed during the exchange (it can become keener for example or decompose itself into sub-goals) and becomes an irreducible final goal on which the exchange ends by a success or by a failure. The success obeys to the double condition of being a *goal reached* and a *goal satisfied* [9].

Goal of the exchange: that which is sustained during the exchange.

Final goal: the state of the world or of the situation at the end of an exchange (it always ends, at least by the agreement of the two speakers about the fact that there is failure when there is failure: the trade unions and the employers have parted on an acknowledgement of failure.). The final goal is not always predictable at the start.

Dialogue : a dialogue consists of a series of exchanges or incidences. There can be many goals in the course of a dialogue.

Strategy of dialogue: the way to handle the talking turns between speakers to lead an exchange or an incidence. The strategy aims at choosing the best direction of fit of the goals at a given moment.

Direction of fit: there are 5 possible directions of fit of the goals that lead to 5 types of strategy:

- H abandons his goal in favor of that of S (reactive strategy), in other words H fits his goal on that of S (in abbreviated form $b_H \rightarrow b_S$)
- H imposes his goal to the detriment of that of S (directive strategy), in other words he forces S to adopt his goal (in abbreviated form $b_H \leftarrow b_S$)
- H and S each keep partially their goal (strategy of negotiation), in other words they do not try to fit their goals *a priori* (in abbreviated form $b_H \leftarrow b' \rightarrow b_S$) even if at the end of the negotiation a compromise b' is found
- H and S take positively into account the goal of the other (strategy of cooperation), in other words they try to fit one to the other (in abbreviated form $b_H \leftrightarrow b_S$)
- H and S abandon their goals for a third one

(constructive strategy), in other words they make a constructive detour (in abbreviated form $b_H \rightarrow b' \leftarrow b_S$)

Let us agree on the following notations:

- b_S : initial goal of speaker S,
- b_H : initial goal of hearer H,
- b_f : final goal of the exchange,
- b_c : conversational goal, supposed to be shared by S and H.

We can then define the following types of strategies (one places oneself in the string, from the point of view of the hearer H:

Non-inferential strategies

These strategies are called non-inferential to the extent where the one who carries them out does not try to find a joint goal with his partner and thus does not have to necessarily infer his goal.

1) Reactive Strategy

Consists in delegating the initiative to S either by making him shoulder his goal (case of a request for help or assistance), or by adopting his goal (case of the servant). The sequence of the dialogue is done:

- by maintaining the goal of the exchange, but without taking an initiative,
- by abandoning one's own goal or by making it pass under the dependence of b_H .

A is passive and S is active. This has the effect of opening any type of strategy to one's interlocutor S. The direction of fit is then $b_H \rightarrow b_S$

2) Directive strategy

Consists in keeping the initiative to lead the dialogue:

- by maintaining the goal of the exchange and by keeping the initiative,
- by imposing one's goal b_H , (thus one tries for $b_S=b_H$)
- by ignoring possibly that of the speaker b_S , who is thus in a way considered as nonexistent.

This has for consequence to impose a reactive or negotiated answer to S and to thus limit the variety of his strategies. H is active and S becomes passive. The direction of fit is then $b_H \leftarrow b_S$,

3) Constructive strategy (or "detour" strategy)

Consists in momentarily shifting the current goal in order to provoke a detour (supposed to be constructive) which is not necessarily an incidence, for example to point out an omission, an error, make a quotation, recall an old fact, an experience, etc.:

The current goal is put on hold, as well as the initial goals, a new goal b is posed, the initiative can be shared.

The direction of fit is then: $b_H \rightarrow b' \leftarrow b_S$. Contrary to an incidence, a detour does not necessarily lead back to the initial exchange; it can leave the conversation unresolved or lead to another detour.

Inferential strategies

C These strategies are said to be inferential to the extent that they require from the part of the two partners a perceptive knowledge of their respective goals. In these strategies the two speakers have a shared initiative.

4) Strategy of cooperation

Cooperation consists in taking into account the goal of one.s speaker by proposing to him one (or several) solution(s) which lead them both to reach their goals, if the latter are not incompatible: this leads to proceed according to a complex process. assess the situation, present an explanation, possibly some examples, some assistance or relevant arguments and to offer a closed choice (because it is more easy from a cognitive point of view for the decision taking), by maximizing the concession space, by going about things through the search for an optimum in a space of possible, by accompanying the speaker up to the solution, by widening the conversational goal if necessary, This has the effect of opening any type of strategy to one.s speaker. The direction of fit is then $b_H \leftrightarrow b_S$.

5) Strategy of negotiation

The negotiation can occur in a situation where the goals are incompatible and when the speakers want to minimize the concessions. The negotiation is carried out on a rather classical pattern, through argumentative sequences (argumentation/ refutation) with a proposal of a sub-optimal solution up to the convergence or acknowledgement of failure. The local tactic is to:

- try to impose one.s goal or to accept a compromise,
- maintain the conversational goal,
- pursue the negotiation as far as possible up to an acceptable goal b_r ,

This has the effect of maintaining one speaker in this comon strategy. The direction of fit is then $b_H \leftarrow b_r \rightarrow b_S$.

The following table summarizes the main properties of the different strategies.

TABLE I. PROPERTIES OF STRATEGIES FROM THE PERSPECTIVE OF THE ADRESSEE (A) RELATIVE TO THE SPEAKER (L)

Strategies	Non inferential			Inferential	
	React.	Dir.	Construct.	Nego.	Coop.
Initiative	S	H	joint	joint	joint
Fit	B_S	B_H	other	non	reciprocal
Conv.goal	maintain	maintain	detour	maintainin	joint

	ing	ing		g	
Concession	max.	min.	without object	min.	max.
Role H	passive	actif	neuter	active	active

IV. SPEECH ACTS

The Speech Acts theory is well known: each speech act is defined by his illocutionary force and the propositional content, according to formalism of Searle and Vanderveken [10].

The dialogic interaction progress using acts (or moves): F^A , F^F , F^{FS} , F^S , F^D , and F^P which have the general form $F_p =$ illocutionary force + propositional content. Each act has prerequisite (named satisfaction conditions) and effect on the world. Certain acts are pure actions ($F^A = to do an action$, $F^F = to order an action$) i.e. for purpose expected in the world (events, facts, achievement of a task), others are with epistemic aiming ($F^{FS} = to ask something$, $F^S = to assert something$) i.e. for purpose in the discourse or on knowledge (mutual or private), and others finally are with deontic aiming ($F^D = to oblige$, $F^P = to offer$) i.e. create obligations (necessity) or offer choices (possibility) for the continuation of the dialogue. These last acts control the interaction and possibly change the rules of the game.

The table, below, summarizes these concepts: Acts, left-hand column, commit speakers A and/or B when they do them, in a certain aiming, taking their source in the background (world, task and private knowledge - K_A indicates knowledge of A, K_B those of B). Their effects relate to a modification of mutual knowledge K_{AB} , plans (elaboration of plans), goals (elaboration of goals) and state of the world.

Speech acts and their functions

Act	Commitment	Aims	Background	Effects
F^{FS}_p	A, B	epistemic	World, K_A	K_{AB}
F^S_p	A	epistemic	World, K_B	K_{AB}
F^P_p	A	deontic	B	Plan
F^D_p	B	deontic	B	Goal
F^F_p	A, B	actionnelle	Goal	World, K_{AB}
F^A_p	A	actionnelle	Goal	World, K_{AB}

V. EXTENDING GAME THEORY FOR DIALOGUE MODELING

The analogy between game theory and games of dialogue has already been addressed by several authors [11], [12]. Their approach is based on "possible worlds" semantics and logics of knowledge and belief, and they have to assume that the participants are rational. For Benz [13], each answer to the question is a problem of decision making, which aims to maximize the utility of the answer among all possible answers. We think that the speaker does not have cognitively the ability to process all possible answers; and to decide which is the most relevant. Probabilistic and numeric approaches are facing

to the problem of quantification and estimation of the value of gains.

Our purpose is to get interesting elements from the game theory for the dialogue modeling, but without considering the dialogue as a defined game. We do not make particular assumptions about the agents and their behavior, to make the dialogue model compliant with the theory. We will assume only this fact: **we think that at each point of the dialogue, speakers are able to know if their gains are increasing or decreasing. They adapt the dialogue according to way their gains are evolving, inside the goal of the dialogue. To do that, they don't compute anything else than calculus of comparisons.**

We present below how we make the analogy between dialogue and game theory with this *method of gradient*.

A. *Types of gain*

During the interaction, the speech acts have effects providing a value system named gains. Greimas [14] argues the gains acquired by the participants can be classified on two axes of values: [having] and [being]. We have to take in account the level of interaction itself, which links the agents in the joint action, and will provide a "joint gain", which cannot be related to the previous axis.

We can detail these kinds of gains (or interest) as :

+*Being*

- Self-esteem. A person's overall appraisal of his or her own worth, in the course of the dialogue, by a reflexive judgment,
- Feeling of positive position. A person's overall appraisal of his or her own worth, by comparing himself or herself to the others in the course of the dialogue,
- Capturing the attention of the other (to captive, to get interest from the others). The feeling that one has of oneself through others.

+*Having*

- Increasing knowledge (knowledge or information about the world, better understanding of the social environment, etc.),
- Progress of the task for which interaction is required (realization of work).

Let's notice here that the value which is acquired is complex and difficult to compute, because it consists in three main factors:

- Utility value: economical value (purchasing, selling, market), informative value (including quality of information and cost to access it),
- Usage value: social (acceptability value), ethical, esthetical,
- Usability value: cognitive, ergonomic.

B. *The joint gain*

We define the joint gain as the "force" of interactional link. It measures the degree of force of what makes the link between participants. The stronger is the link between agents, the more dependants they are of each other. It can consist in an effect of action which is made together, or a common knowledge which is acquired jointly. It represents what is won "with" the other (but not through him). It is the dimension of "alterity" in the dialogue, grounds of inter-subjectivity, mutual understanding, and joint action. The joint gain comes from the interactional level, it consists in four components:

- **Psycho-cognitive:** emotional or sentimental dimension like love / friendship / empathy / care / compassion, etc.,
- **Ethnosociological:** is the social and cultural side, which leads to different types of relations like rivalry / opposition / partnership / connivance / coalition etc., relatively to dimension of individual / group / family / clan/ tribe. One brings out the primary sociality (friends, family) versus secondary sociality (market, nation) [15],
- **Interactional:** (related to praxeology and pragmatics): referential dimension located in space and time immersed in the context of the action as: questioning / investigation / wrangling / exchange /donation, etc.,
- **Ethical:** ethical dimension of alterity like trust / sincerity/ veridicity/ responsibility, etc., which is always involved in face to face.

By his psychological component, joint gain provides the "mood" of the dialogue. This mood is affected by the ethno-sociological environment in which the dialogue takes place (context of rivalry, conflict, cooperation, or neutral in an institutional framework). The interactional and ethical components are built during the dialogue process; they aren't given *a priori* except perhaps in the case of repeated dialogues, when speakers are well knew each from other.

So, these different types of joint gains can be found in dialogue:

+ *Joint:*

- Conviviality, empathy, friendship,
- Partnership in argumentative discussions: if an agent A agrees on B's argument, then position of B is enforced. The gain of B is increased by a joint gain by the fact that A is sharing his argument,
- Cooperation, mutual trust,
- Setting up of coalition or understanding, etc. It provides a strategic advantage ,
- Common purchase of something, that is not divisible, in the course of the dialogue, or share of common experience,
- Knowledge acquired together: the process to acquire this knowledge (for example by dialectic arguments) is

a joint gain because it will serve at a basis for further experience.

Maintaining the dialogue makes itself a joint gain: the process is successful if it is maintained. On the opposite, if the dialogue breaks down, it is a loss. Joint gain receives a negative value in case of conflict as rivalry, aggressiveness.

VI. THE PROGRESS OF DIALOGUE

Our purpose is to highlight the process which makes the dialogue progressing. We have to formalize the progress of the dialogue, the goals which lead it on different levels and how the participants achieve these goals, with their gains and losses in the dialogue game.

A. *Functional approach: the model of competitive games*

We consider that a game consist of rules and stake, and has an initial goal. One can measure by gains and losses how the participants are progressing toward the goal. Each turn talking is a “move” in the game. The move may be for example the negotiation of rules (if they aren’t implicit), a stake, the initial move, an attack, a reply or a diversion.

If a question can be viewed as an attack, the answer can be viewed as (a) an argument which provides a joint gain on the side of mutual knowledge or task realization, (b) a “move” of the game, which is blocking the attack, (c) a refutation which makes the speaker in position of counter-attack or (d) an answer-back or a dodge.

For example in the following dialogue between a seller and a customer, the rules come from bargaining:

V (vendeur) : alors la petite dame comment ça va aujourd'hui ? J'ai de belles courgettes aujourd'hui, toutes fraîches

(V (greengrocer): Hi, how are you today? I've very fine and fresh zucchini)

C (cliente) : ça va bien et vous ? Combien vos courgettes ? C'est pas trop de saison ça dites-moi...

(C (customer) I'm fine, and you? How much these zucchini? It is not seasonal, I think ...)

V : c'est pas cher pour vous, je vous fais un prix, vous êtes belle comme tout aujourd'hui

(V: for you it is very cheap: you're beautiful today)

Etc.

This short dialogue shows clearly how two games are mixed: the game of selling and this of gaining customer loyalty, with seduction. We have to assume here that the scene takes place in a repeated game, to fully understand it.

B. *Principles of dialogue games*

We distinguish in each dialogue:

(a) the game of dialogue maintaining. It is related to social conventions, the rules are often underlying. The speech acts

which contributes to dialogue maintaining are F^P (do-possible) et F^D (do-necessary)

(b) the game of the dialogue itself, linked to the realization of a joint action. At each step we can measure how the goals of participants are satisfied, in term of individual or joint gains.

Dialogue may be part of typical social practice. These kinds of dialogues are well described in the literature; for example between seller and customers, the goal of the customer is to buy at the best price. But in many cases the dialogue is in itself the main activity (social dialogue for instance); in this case it is built by himself without any conventional norm. There are also dialogues that have no apparent purpose other than the user-friendliness - in this case the utility is measured on the scale of wellness or joint gain like create a climate of confidence, etc.

Finally, in many cases, dialogue is included in a typical repetitive practice: it is a situation of repeated game. Speakers have a reputation, they trust each other a priori, and there are external constraints applied to the situation, as well as inheritance from the previous games. In these situations we will use the repeated game theory in order to show the game of trust and power which are at work in this kind of dialogue. There are for example discussions between clients and suppliers, or discussions between colleagues in enterprise. In these dialogues, the joint gain is inherited from previous dialogue; it provides the “psychological context” of the dialogue. Then, this climate will be changed according to the speakers’ behavior during the dialogue.

We will take attention to the dialogues between several speakers: in this case some partial coalitions may emerge, and the notion of joint gain gives more complexity to the utility function. We will make an analogy between these kinds of dialogues and cooperative games.

VII. FORMALISATION

We define a dialogue as:

$D = (B_i, A, S, I, G_i, T)$ where:

- $I =$ set of speakers $\{i\}$
- $B_i =$ goals of speakers i
- $A =$ speech acts $\{F^A, F^F, F^S, F^{FS}, F^D, F^P\}$
- $S =$ set of strategies $\{Reactive, Directive, Cooperation, Negotiation, Constructive\}$
- $G_i =$ set of gains of speakers i where we notice avec les notations $G^E =$ expected gain, $G^C =$ jointed gain
- $T =$ types of games (complet, incertain, repeated, etc.). Each type of game has his proper rules, and the game inherits them if they are not changed by the agents.

As we don’t want to introduce particular logic or digital values which are impossible to compute, we consider that during the game gains only increase or decrease (gradient). Strategies are variables of choices of participants to adjust their gains in the way they increase or became stable. The

algorithm of the computation is very simple: each time other speaker produces speech act, one evaluates gains or losses regarding what is already acquired, and one produce speech act by estimating the expected gains this act can provide.

```

Begin_dialogue
  DJ : Initialization of the new game of type T
  If repeated game then
    Initialize gains with those of previous stage game
  Opening of Dialogue: phatic acts
  Compute expected gain for i which produces: Speech Act Fip
  Interpretation of Fip by other participants according to type T
  (strategies, goals, etc.)
  While Non Equilibrium of gains Do
    For each k de I
      Computing of acquired gain Gk and joint gain conjoint GC
      Computing of expected gain for j which produces : speech act Fjp,
        Aiming to increase Gj + GC i.e GEj > Gj + GC
      Interpretation of Fjp by the others I according to type T
    End For Each
  Evaluation of equilibrium
EndWhile
If new game Then go to DJ
EndDialogue

```

VIII. EXEMPLES

Let's examine the following dialogue, between a customer (a woman) and a greengrocer, on an open-air market.

T = repeated game: yesterday, the greengrocer has sold tomatoes to this woman.

The stake: vegetables on the stall

Rules = buying/purchasing, the price is displayed.

An other game is played in simultaneity: the greengrocer aims to gain customer loyalty: he tells her in informal style.

V (vendeur) : alors la petite dame comment ça va aujourd'hui ? J'ai de belles courgettes aujourd'hui, toutes fraîches
 (V (greengrocer): Hi... how are you today? I've very fine and fresh zucchini)
 C (cliente) : ça va bien et vous ? Combien vos courgettes ? C'est pas trop de saison ça dites-moi...
 (C (customer) I'm fine, and you? How much these zucchini? it is not seasonal, I think...)
 V : c'est pas cher pour vous, je vous fais un prix, vous êtes belle comme tout aujourd'hui
 (V: for you it is very cheap for you: you're beautiful today)
 C : merci, vous êtes gentil [...acte d'achat...]. A demain.
 (C: That's very kind of you, thank you. (...she is buying]. See you tomorrow

It leads to the following formal analysis:

V : F^S(phatic), F^S(x) : zucchini(x)
 S = Directive ; B¹_V = to sell(x) ; B²_V = fidelity(C)
 G^{E1}_V(x) = Benefit(x).Weight(x) avec Weight(x) > 0 ;
 G^{E2}_V(C) = G^{E1}_V(z) : z ∈ X

The greengrocer has the expected gain to secure the loyalty of this customer.

C : F^S(phatic), F^{FS}(y) : selling price(y)
 S = Negotiation ; B¹_C = to purchase(x) : zucchini(x)
 G^{E1}_C(x) > G^{E1}_V(x)

The expected gain of the customer is to get the vegetables at a better price.

V : F^S(y), F^S(phatic)
 S = Negotiation
 G¹_V(x) < G^{E1}_V(x) ; G¹_C(x) = G^{E1}_C(x) > G^{E1}_V(x) ; G^{E2}_V(z)
 The greengrocer is making concession : he is decreasing his immediate gain in order to increase his expected gain (he hopes this woman will come again and buy vegetables in the coming days)

C : F^S(phatic), F^A(buying), F^P
 S = Reactive
 B¹_V et B¹_C satisfied
 for C : G¹_C(x) > G^{E1}_V(x) ;
 for V : G¹_V(x) + G^{E2}_V(z)

The woman has got a discount (G¹_C(x) = G^{E1}_C(x) and G¹_C(x) > G^{E1}_V(x)). The greengrocer has got a positive gain even it is lower than his expected gain, and he has an expected gain that the woman will come again.

It is a situation of repeated game. When the woman will come again, both the participants will get memory of this game, and at the beginning of new game, the greengrocer will have an expected gain G^{E2}_V(z), inherited from the present game.

Dialogue between a homeless (M) and a passer-by (P) (it is a non repeated game)

M : une pièce svp...
 (some little money, please...)
 P : tu ferais mieux de travailler plutôt que de mendier
 (You'd better to work rather than begging)
 M : j'étais au chômage et je n'ai pas trouvé d'emploi
 (I've been unemployed, and I didn't find a job)
 P : ouais, moi aussi j'ai été au chômage...
 (yes, also I, I was unemployed in the past...)
 M : alors vous me comprenez...
 (So, you understand me...)
 P : va te faire voir avec ta pièce
 (get lost !)
 M : bon ça va !
 (Oh... oh... OK...)

M : F^F(x) : money(x) ; B_M = to_get(x) ; G^{E1}_M = value(x)
 P : F^D(to work) ; B_P = 0 ; G^{E1}_P = +being ethic, feeling to do one's duty
 M : F^S(y) : story(y) B_M is maintained ; B_M = to get(x) ;
 G^{E1}_M = value(x)
 P : F^O(z) : story(z), z = y gains do not progress

M: $F^S(\text{expressive})$; G_M^{E1} is increased with +being. *The homeless hopes to get empathy from the passer-by.*

P: $F(\neg x)$; $G_M^{E1} = 0$; $G_P^{E1} = 0$

M: $F^S(\text{phatic})$

The dialogue ends, gains are null on each side.

Positive variant of the same dialogue:

[...]

P: Yeah, me too I've been there...

M: Then you understand me...

P: Yes, I sympathize. Here's a little money

P: $F^S(z)$; story(z); $z = y$

M: $F^S(\text{expressive})$; $G_M^{E1} = +\hat{e}tre$

P: $F^S(\text{expressive})$; $F(\text{money-donation})$;

$G_P = +being + G_{PM}^C$; $G_M = +having$ and $+being$ and $+G_{PM}^C$; G_{PM}^C : sharing a common experience. *Sharing a common experience (empathy of P for M) is the joint gain.*

If P meets M again, he cannot look away. The joint gain creates a mutual debt, and it is put in play in the next stage in case of repeated game.

IX. DISCUSSION

The model we presented is based on estimating the gains progress at the different levels of the dialogue. We don't make any assumption about the intentions of speakers, nor about their cognitive attitudes *a priori*. We only assume that each speaker have a self interest in the dialogue and seek to increase his gains. The cultural and social practice - where the dialogue game takes place (through the social conventions which govern this practice) - leads agents to achieve naturally their goals. That is what we formalize by the "rules of the games".

The rules of the game, the set of social practices (habits, conventions, rituals, etc.) are the common ground that the speakers apply during interaction. They give the context to interpret, to assess the situation strategies, and so on. So it is on a *praxeological* basis that we presuppose the type of the game where the interaction takes place. The rules of the game are implicitly followed by the speakers, so one can infer how the gains are evolving the progress of the gains, without making any assumption on cognitive attitudes of speakers: they are deduced from the type of the game they are involved. So in the example of dialogue in the open-air market, conventional rules of transaction are that the retailer aims to develop the customer's loyalty, whereas the customer aims to buy at better price and to maximize the quality of bought products. Conviviality often occurs in this kind of transaction, both as mean and aim. But, when this transaction happens in a supermarket for example, this dimension does not exist, and expected gains are only related to the products, without involving people. Each kind of game will induce for the speaker different ways to achieve their goals, and to act with others.

The table below summarizes the components of interactional link. It is these elements that give to the dialogue a framework where it will expand. Arrows are indicating a degree of strength, from the most negative to the most positive on each dimension.

TABLE II. COMPONENTS OF INTERACTIONAL LINK

Component	Example
Psycho-cognitive (context)	Violence → Contempt → Suspicion → Indifference → Empathy → Connivence → Friendship → Love
Ethnological, sociological	Rivalry → conflict → collusion → complicity → coalition → alliance → pact
Interactionnal (Behavior)	To do-by (to exploit) → to do against (opposition) → neutral → To do with (cooperation) → to do for (generosity)
Ethic, deontological (Rules)	Duplicity → sinceity → respect → mutual trust

Psychological context, social and cultural environment, provides the rules of the games where the dialogue takes place (context of rivalry, of conflict, or cooperation, or neutral in an institutional framework). Then, the speakers' behavior in the dialogue emphasizes or changes the context of interaction. The gains the participants have got during the dialogue are acquired, but the joint gain is brought into play for the next meeting. Inherited and brought again into play, it is involved in the history of relations.

X. CONCLUSION

After recalling the fundamentals of game theory and showing that a dialogue can be formalized in this theory if we extend the concept of gain, we have shown that one can model the dynamics of dialogue by only estimating how the gains (expected and acquired) evolve during the dialogue. By this way, taking into account the evolution of these gains allows efficient modeling of the dialogue, while avoiding modeling human decision processes or intentionality.

The extended game theory we offer, offers a rich framework for the dialogue modeling: repeated games provide tools to model situations where the dialogue happens regularly in social practice. The gains that have been got at each stage of the game are part of the history. One can get losses (making a concession) at one stage, but progress to the long-term goal. Thanks to cooperative game we model league, coalition, and the evolution of trust among participants. In common social situations, the rules of the games come from a conventional model of social practice, which is the ground of the interaction. In other cases, the negotiation of the rules will be the first game.

At the beginning, the game theory was based on the assumption of rationality of agents, and this assumption led to dramatically simplify the human dialogue. Current developments of the theory in economics include the concepts of culture, institution, and take into account altruism, reciprocity, or emotions. Thus we believe that game theory provides a rich and open framework for modeling the dynamics of dialogue, overcoming the rigidity of conventional and intentional models.

We showed also that a simple gradient computation, without quantitative values estimation and heavy decision process, can significantly reduce the time of mental

computation while making it more credible and more efficient on a cognitive point of view.

BIBLIOGRAPHIE

- [1] D. Vernant, *Du discours à l'action*. Paris : Presses Universitaires de France, 1997
- [2] J. Von Neumann, O. Morgenstern, *Theory of games and economic behavior*, Princeton University Press, réédition 1967.
- [3] L. Carlson, *Dialogue Games: An Approach to Discourse Analysis*, Synthese Language Library, Vol. 17, Dordrecht: D. Reidel. 1983
- [4] M. Hollard, D. Llerena, « Marché et comportements des acteurs dans une filière industrielle : efficacité et équité. » dans *Revue d'économie industrielle*, N°107, 3^{ème} trimestre. pp. 277-293. 2004
- [5] M. Allais, « Le Comportement de l'homme rationnel devant le risque: critique des postulats et axiomes de l'école Américaine », dans *Econometrica*, vol. 21, p. 503-546, 1953
- [6] R. Axelrod, W. Hamilton, *The Evolution of Cooperation*, *Science*, 211, 1390-1396, 1981
- [7] J. Caelen, A. Xuereb, *Interaction et pragmatique : jeux de dialogue et de langage*. Collection science informatique et SHS (sous la direction de C. Garbay), Paris : Hermès éd., 2007
- [8] J. Caelen, *Stratégies de dialogue*. In *Conférence MFI'03 (Modèles Formels de l'Interaction)*. Lille : Cepaduès éd. 2003
- [9] D. Vanderveken, *La logique illocutoire et l'analyse de discours*. in D. Luzzati et al (eds). *Le dialogique*. Peter Lang, 1997
- [10] J.Searle, D. Vanderveken, *Foundations of Illocutionary Logic*, Cambridge : Cambridge University Press, 1985
- [11] L. Carlson, "Logic for dialogue games." *Synthese* 99-3 : 377-415. Dordrecht : Springer, 1994
- [12] J. Hintikka, "Rules, Utilities and Strategies in Dialogical Games". In Vaina, L. and Hintikka, J. (Eds), *Cognitive Constraints in Communications*, Dordrecht : Reidel. 1984
- [13] A. Benz, "Questions, Plans, and the Utility of Answers." In Meier and M. Weisgerber (eds.), *Proceedings of the Sinn und Bedeutung* 8, pp. 51-66. 2004
- [14] A.J. Greimas, *Sémantique structurale*. Paris : Larousse, 1966
- [15] A. Caillé, *Critique de la raison utilitaire*, Paris : ed. La Découverte, 1989