Interactions in a Collaborative Decision-Making Process: Disturbances or Control Variables?

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Abstract: A group of agents is faced with collective decisional problems when trying to solve a complex problem together. The agents must cooperate to efficiently establish which alternative appears to be a convenient consensus. The corresponding debate is seen as dynamical process that we propose to analyze and control. Its dynamics depends on the strategy the agents argue their choices and on the intervention order in the debate. The influence an agent may have upon the other ones may appear as a disturbance in the deliberation process except if it is used to control the debate dynamics.

Keywords: Influence index, argumentation, collective decision, social network

1. Introduction

This paper deals with the involved dynamics of a collective decision-making process as soon as a group has to solve a common complex problem. The agents have first to efficiently determine which alternative must be chosen to solve the problem. This study is limited to the binary but common situation where two options ± 1 are involved. It is assumed that each agent has an inclination to choose one of both alternatives ± 1 which, due to influence of other agents, may be different from the decision of the agent [1]. The agents' opinions may vary in time in a group dynamics that obeys to social influences phenomena [1][2] and to agents' argumentation strategies [3-5]. Thus, the agents' intervention order in the debate clearly determines the group decision. The social influence of an agent may then be considered as a disturbance in the deliberation process except if it is relevantly used by the debate manager to govern the discussion.

Collective decision-making in a crisis cell is typically such a dynamical process. It is at the origin of this study that takes place into the works developed in the framework of the ANR project Isycri [6]. Crisis is depicted as the interpretation of a situation where human beings are confronted with an imminent or established risk. This interpretation may be questioned as soon as further serious or complex factors appear. The crisis cell's agents must be able to face with such an adaptable model: they must efficiently deliberate in accordance with their available pieces of information to choose the adequate representation and then carry out a coordinated actions plan. The debate manager of the crisis cell has to efficiently control the debate to converge to the most consensual decision as possible [7].

A negotiation dialogue emerges from a conflictual situation when two individual agents are compelled to cooperate to solve a common problem [4]. The most common example of such a situation takes place when rare resources are to be shared (a crisis situation is a typical case of such a phenomenon). An agent would like to carry out an action but the required resource to achieve this action belongs to another agent. There is a conflict when the second agent needs this resource too in order to perform an action in accordance with his own preferences. The agents are then supposed to exchange offers and counter-offers, supported by well-argued speech, to establish a consensual sharing of the resource. The aim of any agent is to maximize his attributed part of the resource, while preserving an acceptable consensus which is the collective aim of the dialogue. The agents are cooperative agents, i.e., they are supposed to make concessions with regard to their personal objectives to achieve a consensual agreement [4].

In this approach, deliberation is seen as dynamical processes whose results depend on the order the arguments are exhibited. Each agent has his own beliefs and exerts an influence on the other agents. His intervention on behalf of any alternative may be decisive at any time, i.e., his proposal may be collectively considered as an acceptable compromise at any time finishing the deliberation. In our application domain, let us note that a decision is necessarily required even when not unanimously accepted. A collective decision can thus be disturbed by the order the agents intervene in the debate. To derive benefit from this phenomenon, the influence an agent may exert on a social network can also be seen as a control variable to govern the debate. For this purpose, the influence of each agent must be estimated on line and used to control the dynamics of the deliberation process. The envisaged control here merely consists in appointing the most influential agent as the next speaker. Indeed, he is supposed to bring several agents round. He is theoretically the participant who can modify the dynamics of the deliberation the most likely and then conclude the deliberation as quick as possible (the consensus convergence cannot nevertheless be warranted).

Section 2 points out the concept of influence in a social group. The dynamics of a deliberation process is also discussed. Section 3 proposes a breakdown of the deliberation process into elementary steps. The order the agents intervene and the way they choose their arguments for or against an alternative determine the dynamics of the debate. The aim is to change its response time through the concept of influence: the next speaker is selected with regard to his potential influence in the debate. The model of the argument process is provided by [3-5] and the control of this deliberation is based upon the statistical model of social influence proposed in [1]. This influence model is modified to be integrated in our dynamical model. Social influence is thus considered as the control variable of the deliberation process. Section 4 introduces the probability an agent will choose an alternative rather than the other one with regard to his knowledge base. This probability is a time-varying variable that justifies the dynamical aspect attributed to the decisional power of an agent in this cybernetic interpretation of a debate.

2. Influence and dynamics in a debate

In a recent paper, Grabisch and Rusinowska have proposed a model of influence in a social network [1]. It is assumed that each agent has an inclination to choose +1 or -1 which, due to influence of other agents, may be different from the decision of the agent. The point of departure is the concept of the Hoede-Bakker index—the notion which computes the overall decisional 'power' of an agent in a social network (n agents). The definition of this index was provided in 1982 [8]:

$$\mathrm{GHB_j(B,gd)} = \frac{1}{2^{n-1}} \cdot \sum_{\{i|i_j=+1\}} \mathrm{gd(Bi)} \qquad [1]$$

where i is an inclination vector in $I = \{+1,-1\}^n$ that models the agents' inclinations, $B: I \to I$ is the influence function and the decision vector Bi is a n-vector consisting of ones and minus ones and indicating the decisions made by all agents, $\mathrm{gd} : \mathrm{B(I)} \to \{+1,-1\}$ is the group decision function, having the value +1 if the group decision is +1, and the value −1 if the group decision is −1.

The main drawback of the Hoede-Bakker index is that it hides the actual role of the influence function, analyzing only the final decision in terms of success and failure. The decision is successful for an agent as soon as his inclination matches the group decision. In their paper, the authors separate the influence part from the group decision part, and propose a modified index of decisional power where the decision of the agent must coincide with the group decision to be a success for the agent.

In [1], the notion of influence relies on preliminary notions as the influence of a coalition upon an individual. We briefly summarize them in the following. Let S be a coalition and note:

$$I_S = \{i \in I / \forall k, j \in S / i_k = i_j\},$$

$$I_{S\to j} = \{i \in I_S / i_j = -i_S\}$$

$$I^*_{S\to j} = \{i \in I_{S\to j} / (Bi)_j = i_S\}$$

where i_S is the inclination of coalition S.

The possibility direct influence index of coalition S on a_j is (number of times the final decision of a_j coincides with the choice of S relatively to all the situations a_j initially disagreed with S, independently of the opinions of all others agents in $\overline{S}$):

$$\overline{d}(B, S \to j) = \frac{\left|I^*_{S\to j}\right|}{\left|I_{S\to j}\right|} \qquad [2]$$

With the same notations, the necessity direct influence of S on a_j is:

$$\underline{d}(B, S \to j) = \frac{\left|\{i \in I^*_{S\to j}(B) / \forall p \notin S[i_p = -i_S]\}\right|}{2} \qquad [3]$$

(no agent in $\overline{S}$ can have influenced a_j).

Finally, the weighted direct influence index of coalition S on agent a_j is:

$$d_\alpha(B, S \to j) = \sum_{i \in I^*_{S\to j}(B)} \alpha_i^{S\to j} \Big/ \sum_{i \in I_{S\to j}} \alpha_i^{S\to j} \qquad [4]$$

where $\alpha_i^{S\to j}$ is a weight attributed to the influence of S on agent a_j under the inclination vector i (this weight enables to weight the influence of S and can be envisaged as a function of the number of agents in $\overline{S}$ with the same opinion as S). The weights distribution $\alpha_i^{S\to j}$ provides a large variety of models of influences.

Lastly, the modified decisional power, which allows the inclination vectors to be unequally probable, proposed in [1] is:

$$\phi_j(\mathrm{B,gd,p}) = \sum_{\{i\,|\,(B_i)_j=+1\}} \mathrm{p(i)gd(B_i)} - \sum_{\{i\,|\,(B_i)_j=-1\}} \mathrm{p(i)gd(B_i)} \quad [5]$$

where $\mathrm{p} : \mathrm{I} \to [0,1]$ is a probability distribution.

One of the conclusions of [1] concerns the integration of dynamical aspects in the influence model. Indeed, the authors' framework is a decision process after a single step of mutual influence. In reality, the mutual influence does not stop necessarily after one step but may iterate. From a control theory point of view (to our mind), the authors propose to study the behavior of the series of B powers to find convergence conditions, and to study the corresponding decisional power. They also suggest envisaging the influence function as a probabilistic function.

Rico et al. [2] had already evocated dynamical aspects in a debate. The consensus to be established still concerns the choice ± 1. The authors discuss the way the preferences of the agents may vary in time during the debate due to influence of other agents. The semantics of influence is not the same as in [1]. It is based upon a multi criteria framework to model the relations of influence between the agents during the debate [9]. A capacity $\vartheta: 2^A \to [0,1]$ where $A = \{a_1, \ldots, a_n\}$ is a set of n agents represents the relative importance of all coalitions $B \subset A$ in the group, with $\vartheta(\emptyset) = 0$, $\vartheta(A) = 1$, $\vartheta(B) \le \vartheta(B')$ when $B \subset B'$. Given two agents a_1 and a_2, if $\vartheta(a_1) + \vartheta(a_2) < (\text{resp.} >)\ \vartheta(\{a_1, a_2\})$, then there is a positive synergy (resp. negative) between a_1 and a_2. This interpretation of influence is the basic concept that supports the preferences' revision model in [2]. The preferences of an agent a_i evolve each time an agent a_j intervenes in the debate.

To our mind, the main contribution of [2] concerns the revision model. They propose a dynamical model for the conviction and the preference of an agent. During the debate, each agent can express his opinion. The other agents may revise their opinion relatively to their interaction with the speaker. When the conviction of an agent becomes too weak, he can then change his preference. His new conviction is determined from his previous own conviction and from the conviction of the speaker. The corresponding function is a Sipos integral. From a control point of view, their model should be considered as the state equation of conviction. It could be synthetically enounced: $c_j(k+1) = F(c_j(k), \pm c_s(k))$, where c_j is the conviction of agent a_j after agent a_s intervenes. This non linear equation provides with the conviction of a_j at time $k+1$, the preference is then computed. When the order the agents intervene is arbitrary, then it can take a long time before a consensus is achieved and this consensus depends on the order the agents speak. To that end, the authors propose to appoint the next speaker : they compute the necessary number of times each agent should intervene to change at least one preference among the agents with an opposite preference. The agent with the minimal score is the next speaker.

As a conclusion, [2] first proposes a state equation that models the evolutions of the conviction of an agent in time. Then, it provides a mechanism to control the convergence towards a consensus. This thought process is close to the design of control loops in automatics. Thus, this dynamical representation appears as a relevant model for control purposes and debate governance. Nevertheless, the notion of argument is not introduced in this modelling: the dynamics of the debate would be independent on the relevancy of the arguments, but would only depends on the social interaction of the agents. A possible evolution of the model in [2] would be to combine the influence of an argument and the social influence of the agent in the state equation. The revision process of preferences should then include the mechanisms of an argumented negociation. The models then rather come from artificial intelligence than from games theory.

Indeeed, games theory reduces negociation to exchange offers and counter-offers until the best compromise is reached (the meaning of “best” may be discussed [10]). Apart from the modeling assumptions in games theory approaches, another drawback is that no information exchange about offers is allowed. Therefore, the way an agent justifies his choice to make his choice understandable by the other ones should efficiently improve the mutual search for a compromise [4].

Amgoud and Prade have proposed an attractive framework to introduce arguments in negotiation [3-5]. They explain why argumentation can support the agents’ reasoning in a negotiation. In their inference model, an argument is a rule whose premises bring a justification, an explanation or a proof for the conclusion. Arguments are deduced from the beliefs and the objectives of an agent. An argument arg of agent a_j is composed of pieces of knowledge, one alternative x and one goal that is satisfied or not when alternative x is kept. Decisional arguments may be for (PRO) or against (CON) alternative x. A preference order may be defined on the arguments: it is related to the certainty degrees of the constituting pieces of knowledge of arguments and the degrees of priority of the goals they attack or defend (force of an argument). An agent can then choose the most suitable arguments w.r.t his strategy at any time in the debate. A pessimistic qualitative utility [11-12] is introduced to evaluate options and computed from agents’ knowledge bases. The preferences of agents vary in time according to the relevancy of exhibited arguments.

The agents’ reasoning, their strategies and the protocol of interaction determine the order the arguments are going to be exhibited during the debate. Thus, there are determinant parameters to the dynamics of the deliberation. A protocol essentially consists on a set of rules that govern the right behavior of interacting agents to produce dialogues. Several parameters may define a protocol, in particular the parameter that defines the order the agents speak. Protocols may be more or less flexible, but they all consist in a set of rules that a priori determine the dynamics of the debate. As a consequence they cannot be considered as a dynamical control of the debate.

In our proposal, agents do not speak in turns. The next speaker is dynamically pointed out to speak: the most influential agent is chosen. Indeed, he is supposed to be the agent who can a priori win a majority the most likely at a given time. When new arguments are introduced in the debate, the agents reconsider their perception of the situation, and then the probability of their inclination to say ± 1 is changed in equation (5). We suggest using the model of influence proposed by Grabisch and Rubinowska to govern the debate: the decisional power index is computed each time an argument is exhibited from the new inclinations probability distribution. Several controls may be envisaged depending on the application: accelerating the convergence to a consensus, avoiding groupthink phenomena or forcing the hand of destiny. In this paper, the control merely consists in identifying the most influential agent to be the next speaker. The dynamics of the debate is thus a priori supposed to be speeded up.

Our proposal is close to the ideas developed in [2]. [3-5] provide the models to simulate the mechanisms of argumentation in a negotiation, [1] furnishes the notions necessary to define a control loop in the deliberation process. The articulation between both models is: the up-dating beliefs of agents when a new argument is introduced modify the inclinations distribution probability in equation (5); hence the decisional power index and the corresponding statistical analysis. We then suggest an estimation of the probability distribution. The power index is up-dated and can be seen as the actuator variable in our cybernetic framework.

3. The steps of deliberation

The deliberation process is broken down into steps as suggested in psycho sociology [13] where three main phases are emphasized: data gathering, evaluation and influence. Figure 1 proposes a cybernetic interpretation of this dynamical process. In that scheme, the process to be controlled is deliberation, the controlled variables are utilities of alternatives, and social influence is the actuator signal.

Let $A = \{a_1, \dots, a_n\}$ be a group of agents and $X = \{-1, +1\}$ the set of alternatives. Let us now describe the steps of the deliberation process represented in figure 1. The control function requires identifying the most influent agent because he is a priori the most likely agent to win a majority. At least, he is assumed to be the most influent agent to speed up the dynamics of the debate towards a consensus (i.e., when the utilities attributed to the options by the agents do not evolve anymore). The most influent agent is the next speaker. He exhibits a new argument. The other agents take into account this argument in their perception of the situation (the utilities are up-dated and a new probability distribution is provided for the inclinations). The individual decisions can be computed. When the utilities accorded to the options by the agents do not evolve anymore, the inclinations probability distribution is stable. It means that there is no more relevant argument able to modify the agents' assessments. Then, the group decision can be made (figure 1).

Choice of the most influential agent: each time an argument is exhibited (at time t), the most influential agent $a_{VIP(t)}$ must be identified (figure 1). The decisional power index in equation (5) is computed to appoint him. He is statistically the most likely agent whose decision coincides with the group decision. Most agents thus should come round to his opinion. It is expected that he has relevant arguments to support his "leadership" potential.

Introduction of a new argument: Agent $a_{VIP(t)}$ chooses his most suitable argument w.r.t. his beliefs and goals bases at time t. It is assumed that he adopts a cooperative strategy [4]. He may choose an argument PRO to defend his preference or an argument CON to attack the other alternative.

Computation of inclinations: In this step, it is assumed that each agent a_j can assess the alternatives in X at any time t. This assessment is based upon a pessimistic qualitative utility function $E_{*_j}^{t} : X \to [0,1]$ as defined in [11-12]. Each agent computes the utility of both alternatives in X from his knowledge base augmented with the argument provided by $a_{VIP(t)}$. Then, we construct the vector of inclinations of agents at time t, i.e., the a priori current preferences of agents for ± 1 if the deliberation should stop here. Let us note this vector $i(t) \in I = X^n$.

Computation of the probability distribution associated to the inclinations vectors: a probability distribution must be affected to the inclinations vectors $i(t) \in I = X^n$ to perform the statistical model in equation (5). The intuitive idea we propose consists in claiming that the greater the difference between the utilities of +1 and -1, the most probable the inclination of an agent. The inclination probability of each agent is a function of this difference. Then, the probability distribution of vectors $i(t)$ is computed.

The inclinations probability distribution must be up-dated each time an argument is exhibited since the utilities change. The decisional power is thus a time-varying variable and can be seen as a control variable (figure 1).

Computation of the decision: the decision vector $Bi(t)$ is computed from the influence function B and the vector $i(t)$ if the debate should stop at t.

Convergence: as soon as the utilities accorded to each alternative in X by the agents do not evolve anymore, the inclinations probabilities do not change. The group decision can be computed with $gd : I \to X$ (figure 1).

The utilities have been chosen to be the actuator variables in the control loop (instead of the probabilities) because they appear to us as the most semantically natural: the debate becomes no more useful when the agents do not change their position anymore.

4. The associated models

In this section, the necessary computations to design the previous control loop are proposed. The relation between utilities and probabilities is emphasized.

The pessimistic qualitative utility: [4] proposes to qualitatively assess an option according to the beliefs and goals of an agent w.r.t. an alternative. A possibilistic model is proposed to capture the perception of agent a_j. Two stratified knowledge bases capture the mental perception of agent a_j. Having $K^j = \bigcup_{k=1..l} K_k^j$ stratified means that some pieces of knowledge are considered fully certain, while others are less certain (maybe distinguishing between several levels of partial certainty such as "almost certain", "rather certain", ...). Respectively, a stratified base of goals $G^j = \bigcup_{k=1..l} G_k^j$ means that some goals (resp. rejections) are imperative, while some others are less important [5].

Let us then consider a possibility distribution π_d which constrains the plausible states that can be reached when a decision d is made and μ is a qualitative utility function. They are both applications defined on a finite set of interpretations Ω to a linearly ordered finite scale $U = \{0,1,..,l\}$. A pessimistic qualitative utility of d is defined as:

$$E_*(d) = \min_{\omega \in \Omega} \max(\mu(\omega), inv(\pi_d(\omega))) \qquad [6]$$

Each agent a_j has to assess the pessimistic qualitative utilities $E_{*j}(x)$ for any $x \in X$ according to his K^j and G^j knowledge bases each time an argument is exhibited (figure 1). The new argument is integrated in the knowledge bases K^j at the level that corresponds to the degree of certainty the speaker attributes to his own argument. That is a very naive assumption as proposed in [4], but it is not the matter of this paper.

The inclinations probability distributions: When the utilities for any $x \in \{-1; 1\}$ have been computed, then the inclination for any agent a_j is envisaged. The inclinations probability distribution necessary to the statistical model in (5) must be established. As previously mentioned, the probability an agent a_j is inclined to choose one option $\max_{x=\pm 1} E_{*j}(x)$ is related to the difference $\left|E^t_{*j}(+1) - E^t_{*j}(-1)\right|$ between the qualitative utilities of $+1$ and -1. When agent a_j estimates the utility of each alternative, it is assumed that he has an inclination which is more or less marked depending on the utilities difference. Let us represent the choice of agent a_j by a discrete Bernouilli random variable X_j ($X_j = \pm 1$). The difference of qualitative utilities $\left|E^t_{*j}(+1) - E^t_{*j}(-1)\right|$ is the number of levels there are between both utilities (probabilities have been nevertheless represented as continuous functions of $\left|E^t_{*j}(+1) - E^t_{*j}(-1)\right|$ for graphical clarity purposes in figure 2).

Let us consider the function that links inclinations probabilities and utilities differences. Basically, one can imagine that as soon as the utility difference is positive, then the agent expresses a preference (Figure 2a). It may also be supposed that below a given threshold, the difference in gain is seen as insignificant and the agent's choice does not really result from this difference (Figure 2b). In this case, a threshold ε_j is to be introduced to define the probability of x_j. It can then be assumed that this threshold cannot generally be precisely defined, it is simply known that it belongs to an interval (Figure 1c). The probability choosing x_j when the utilities difference takes its value in this interval is a strictly monotonous function of the utilities difference. In the example in figure 2c, the bounds of the interval are assumed to be symmetric. Several monotonous functions may be envisaged. In this article, we consider an affine approximation in the interval $[-\varepsilon_j;\varepsilon_j]$. This choice can be justified in the following way. The threshold ε_j corresponds to an imprecise value beyond which the gain (the difference between utilities) choosing one alternative and not the other one are sufficiently significant to confirm the agent's opinion. It is modeled as a random variable E following a uniform law on $[-\varepsilon_j;\varepsilon_j]$. Its value is $1/2\varepsilon_j$ (reasonable assumption without more information) and $p_j(X_j = +1) = P(\mathrm{E} < E^{+1}_{*j} - E^{-1}_{*j})$, respectively $p_j(X_j = -1) = P(\mathrm{E} < -(E^{+1}_{*j} - E^{-1}_{*j}))$ (Figure 1d).

This provides the probability p_j that the inclination of agent a_j is ± 1 at time t, i.e., the probability of $i_j = \pm 1$ as a function of the utilities difference at time t. The probability on inclinations vectors can then defined:

$$p : I \to [0,1] \text{ such as } p(i) = \prod_{j=1}^{n} p_j(i_j) \qquad [7]$$

Independency assumption holds because $\forall j, [-\varepsilon_j;\varepsilon_j]$ are subjective data related to the frame of mind of each agent a_j.

In conclusion, from his mental representation of the situation, K^j and G^j knowledge bases at time t, agent a_j evaluates $\left|E^t_{*j}(+1) - E^t_{*j}(-1)\right|$ through equation (6). Hence, his inclination probability and the probability distribution $p(t)$ on the inclinations vectors $i(t)$ are computed at time t through equation (7). $p(t)$ appears as a time-varying function of the state of knowledge.

Most influential speaker: Knowing the probability distribution of inclination vectors, the decisional power of each agent is computed at time t with equation (5). Then, the most influential agent is supposed to be the most likely agent that will a priori win a majority and he is thus the next speaker at t+1. $a_{VIP(t)}$ chooses the argument with a maximal force in his knowledge base [4].

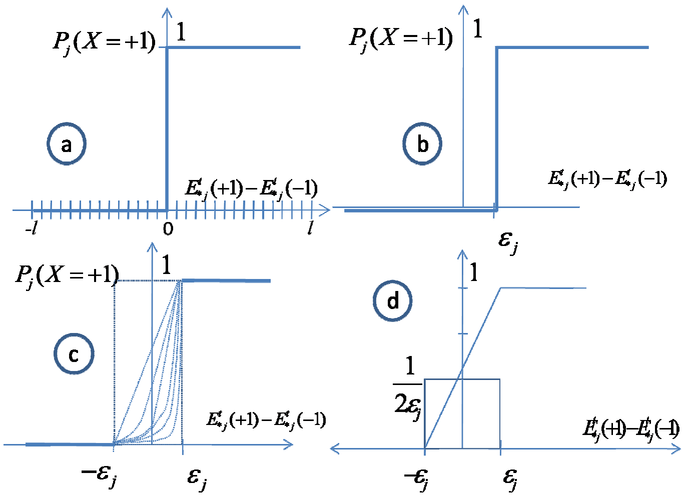

Figure 2: inclination probability of agent a_j and utility difference (gain)

In practice, one can imagine that the agents entrust the crisis debate manager in our application with their a priori intention (I will "almost certainly", "rather certainly",…). The debate manager can then estimate the inclinations probability distribution necessary to efficiently govern the debate.

5. Conclusion

This paper proposes a dynamical model to simulate a debate when a group of agents must cooperate to efficiently establish which alternative appears to be a convenient consensus. The protocol that governs the way agents speak in turns and their argument strategies are determinant characteristics to the conclusion and the dynamics of the debate. In our approach, a priori constraints on the order agents speak in turns are replaced with a dynamical control of the debate. The influence of an agent in a social network is the actuator variable of this control. The modified decisional power of [1] is the model of influence that supports our proposal. It allows the inclination vectors to be unequally probable. A proposal is made to link the inclinations probability distribution to the state of knowledge of agents at any time, and more precisely to the utilities difference between competitive alternatives in the debate. The beliefs of the agents evolve in time once an argument is exhibited, then the utilities and the inclinations probabilities are time-varying variables. Hence, the decisional power has to be up-dated each time an argument is exhibited. This principle appears rather natural. Indeed, among others, it means that the social influence of an agent depends on the more or less marked convictions of the other agents: the notion of conviction in [2] would be the inclination probability in our framework. Thus, the decisional power is a time-varying variable itself and can be used as the actuator signal in the control loop of debate.

The main subject of this paper is to present our cybernetic viewpoint to analyze and control a debate. The control proposed here is elementary. The next speaker is the most influent agent at time t. It does not warranty an accelerated dynamics of the deliberation. It can only be expected that this agent who is the most likely to win a majority, will play a leading role providing relevant and significant arguments. Further controls may be envisaged on the concept developed in this paper: choosing the most influent agent among the opponents of the current proposal in order to avoid any groupthink phenomena for example.

Another improvement to our model concerns the way a new arguments is integrated in the knowledge bases of the agents. Indeed, as mentioned in the paper, this new argument is naively integrated in the stratified knowledge bases at the level corresponding to the certainty degree the speaker affects to his argument (as proposed in [4]). The integration level should take into account the influence of the speaker and the beliefs revision mechanisms would then be more relevant.

6. References

[1] Grabisch, M., Rusinowska, A.: "*A model of influence in a social network*". Business and Economics. s.l. : Springer Netherlands, 2008.

[2] Rico, A, Bonnevay, S., Lamure, M., Tounissoux, D.: "*A debat modelisation with the Sipos integral*", LFA 2004, Nantes, 2004.

[3] Amgoud, L., Belabbes, S. et Prade, H. : "*Recherche de consensus entre des agents : une approche possibiliste basée sur l'argumentation*", LFA, 2004, Nantes, France.

[4] Belabbès, S. : "*Contribution aux systèmes de délibération multi-agent : une approche argumentative*", Ph.D. thesis, Toulouse : Université Toulouse III, 2007.

[5] Amgoud, L., Prade, H.: "*Using arguments for making and explaining decisions*", Artificial Intelligence, 173(3-4): 413-436 (2009).

[6] Benaben, F., Hanachi, C., Matthieu, L., Couget, P., Chapurlat, V. : "*A Metamodel and its Ontology to Guide Crisis Characterization and its Collaborative Management*", 5th Int. Conf. on Information Systems for Crisis Response and Management, ISCRAM, 2008, Washington, USA

[7] Couget, P., Benaben, F., Lauras, M., Hanachi, C., Chapurlat, V.: "*Information Systems interoperability as a way to Partners Integration in a Crisis Context*", 20th Int. Conf. on Software & Systems Engineering and their Applications, ICSSEA'07, 2007, Paris, France.

[8] Hoede, C, Bakker, R.: "*A theory of decisional power*", Journal of Mathematical Sociology", 1982. 8:309-322.

[9] Grabisch, M., Perny, P. : "*Agrégation multicritère*", In B. Bouchon and C. Marsala, editors Utilisations de la logique floue. 1999, Hermès.

[10] Labreuche, C. : "*Une approche basée sur les coalitions en décision de groupe*", LFA'07, 2007, Nîmes, France.

[11] Dubois, D. & Prade, H.: "*Possibility theory as a basis for qualitative decision theory*", 14th Intl Joint Conf on Artificial Intelligence, IJCAI. Montréal, Canada, 1995. pp. 1924-1930.

[12] Dubois, D., Prade, H., Sabbadin, R.: "*Decision theoretic foundations of qualitative possibility theory*", European Journal of Operational Research, 128, 459-478, 2001.

[13] Anzieu, D. et Martin, J.Y. : "*La dynamique des groupes restreints*", PUF, 1982.

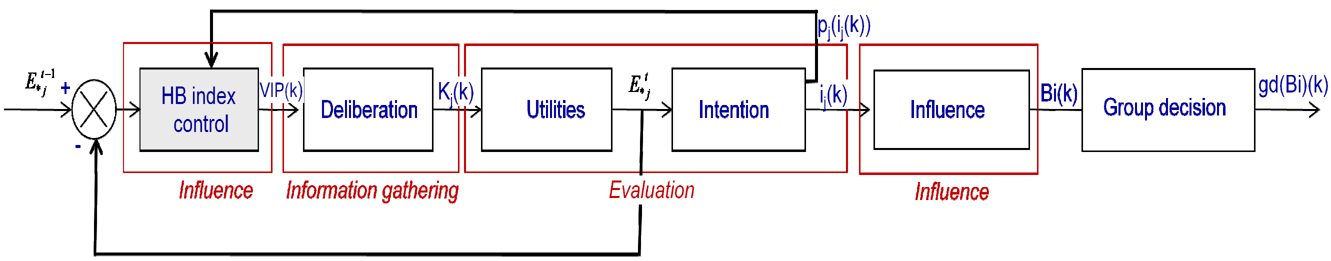

Figure 1: a cybernetic interpretation of the dynamical process of deliberation