Improving performances in a company when collective strategy comes up against individual interests

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Abstract

In the current industrial context, strategies intended to bring about continuous improvement have to include the multi-criteria performance expression aspects. In complex systems, many actions may be envisaged to achieve the required levels of performance. A fuzzy representation is used to model the relationships between objectives and actions. Mostly, the potential improvement actions are distributed into several departments of a company. Then, the departments have to enter into negotiations to allocate actions' responsibility and share the budget granted by the direction. Lots of interest conflicts may occur. An argumentation framework is proposed to model this argumented negotiation for improvement design.

Keywords: industrial performances, argumentation, multi criteria improvement, debate modelling, qualitative model.

1. Introduction

To deal with the complexity of the current industrial context, new diagnosis/control strategies intended to bring about continuous improvement have to include the multi-criteria performance expression aspects and the modelling of their relationships [2][4]. Indeed, control strategies have to define, compare and choose action plans (*i.e.*, a subset of actions) with regard to the relationships between performance expressions, the expected level of performances to be reached and the allocated ressources [2]. Computing the least costly action plan to reach multiple objectives may appear as a multicriteria optimization problem. Some attempts have been proposed to design such an efficient multicriteria improvement based on a Multi Attribute Utility Theory (MAUT) model [3]; other approaches [7][8] explain that a muticriteria improvement project should rather be based upon a model of the relationships between actions on the system and goals. Some trade-offs between both trends have been suggested in [11][12].

Furthermore many methods or actions are generally liable to improve this multicriteria performance, and it rapidly raises a severe combinatorial problem. An action may improve a performance but distracts from another one [7]. Finally, several departments are generally in charge of groups of improvement actions. They must cooperate to achieve the improvement goals. It is a thorny problem because a department does not necessarily know the capacities of other ones. Interactions between departments may be distorted by antagonist personal interests and the coordination may suffer a lack of communication. Conflicts of interests may appear and cooperation may become competition. An efficient collective monitoring necessitates among others that the goals and functions of communication between departments are clearly revealed (collaborative exchange of actionable knowledge) and the key of group dynamics are elucidated (identification of personal and collective goals). Instead of a global combinatorial optimization problem, designing a collective improvement project thus appears as an organizational decision [15]. Exchanges of knowledge useful to action are filtered by organizational constraints because collective and personal goals are vaguely mixed up. At last, the improvement actions that are selected generally do not correspond to a global optimum with regard to improvement costs. However, they satisfy performance objectives and budget constraints that are imperative to the executive board of the company on one hand; and they result from a consensual negotiation between departments on the other hand. The executive board shall validate the decision even if it is probably suboptimal. A satisfying reasonable solution is thus achieved despite this information filtering process by the organization. This is characteristic of organizational decisions and is at the origin of the concept of decision-makers' bounded rationality: the bounds on knowledge of facts and hypotheses in decisions are due to the constraints of the organization, which selects or favors certain scenarios according to its own interests [15]. Modelling the design of an improvement project as a global multi-objective optimization problem thus appears as an unrealistic assumption from Simon's point of view because constraints of the problem are not a priori known and must be progressively learned by departments.

In this paper, the collective choice of improvement actions is thus modeled as a debate. Departments exchange arguments and negotiate the way actions will be distributed. Decision-making is a process: it is constructed, negotiated and follows a sinuous path over time [13][14]. The decision process is modeled as an argumented negotiation in the framework of argumentation theory [1][6].

Hence, this paper proposes an original model to collectively identify a relevant action plan that provides the expected performances improvement. Departments are considered as collaborative agents: they make their possible to reach collective objectives although they have also personal interests in the project. The more actions are carried out in a department, the greater his budget. The proposal of a department relies on his knowledge of relationships between his actions and the goals he claims to achieve. An argumented negotiation is thus started until all the performances are claimed to be improved at a global cost below the financial upper bound.

Let us provide afferent notations to formalize the search of an action plan by a collective of collaborative agents. First, $C*$ is the subset of criteria to be improved and B the maximal allocated budget. A group of M agents $\{m_1,..m_l,..,m_M\}$ has to determine which subset of actions AP, *i.e.*, an *action plan*, should be carried out to fulfill the objectives in C^* under the financial constraint B. Each agent m_l is a department who is in charge of a subset of actions $A(m_l)$. An action in $A(m_l)$ may improve some criteria in $C*$ but may also distract some other ones, thus the search of an action plan shall manage such conflicts. Improving criteria in C^* is the common goal of the departments. However each of them has a financial interest in the improvement project. Indeed, the more actions of m_l are in the action plan, the greater the percentage of B returns to department m_l. The part of budget B for m_l department is: $\sum_{a\in A(m_l)\cap AP} c(a)$ with $c(a)$ the cost of action a.

The approach proposed here relies on an argumented negotiation between departments. The related model is formalized in Dung's argumentation framework. Finally, the approach is supported by a simulator of the departments' debate. This modelling is motivated by the following purposes:

- First, when the set of potential actions is large then using a global optimization method rapidly leads to combinatorial problems [11][12]. Simulation techniques where departments are independent but cooperative agents allow reducing complexity of computations. A department m_l only uses a local optimization model to compute a partial improvement. This modelling is better suited to practical situations where each department controls his own know-how, and only shares the part of his knowledge which is required achieving the global objective, defending his own interests and not necessarily revealing his weaknesses;
- Secondly, the debate simulation may be envisaged as a decision-support system by a department m_l (or a group of departments) during the real debate to optimize his own interest;
- Third, simulating the outcome of the argumented negotiation may be a posteriori used to check that the final decision actually relies on rational criteria (costs minimizations, fair resources sharing, etc). In this case, the purpose of our support system is rather explanation or justification;
- At last, the debate is seen as a dynamical process in this simulation approach. Hence, it can be envisaged to control this dynamical model: the decision support system could help the executive board governing the debate between his departments in order to improve the convergence of the debate or better share the allocated resources.

This approach is divided into two major steps. First, a fusion model is proposed to combine effects of actions upon performances and then, assess the global worth of an action plan. Then, an *argumentation framework* is proposed to model the argumentated negotiation. The plan of the paper is the following. Section 2 provides the fuzzy model of relationships between actions and goals. It is inspired from Felix's model in [7]. It concludes with some related actions consistency properties. The other sections are dedicated to the debate modelling. Section 3 provides some essential reminders related to Dung's theoretical argumentation framework. Section 4 describes the agents' knowledge bases in this framework: decisional arguments consist in providing partial action plans to contribute to the improvement project. Section 5 is related to the debate organization. First, attack and preference relations between arguments are introduced. Then, decisive factors and strategies of departments, knowledge sharing process are introduced. An illustrative case study is finally proposed.

2. Admissible actions

This section first provides the relationships model between actions and performances as proposed by Felix in [7][8] ; then a computation based upon this model is proposed to assess the worth of any action plan.

2.1. Actions – Performances relationships model

First, the set of potential actions is $A^0 = \bigcup_l A(m_l)$ and $A(m_{l=1..M})$ is a partition of A^0. Let us note $P_i, i = 1..n$ the performance related to criteria in C^* and $a_{j=1..p}$ improvement actions in A^0. For each performance P_i (performance P_i and criterion i are equivalent and indifferently used in the following), we denote S_i the set of actions a_j that support an improvement of P_i and D_i the set of actions $\overline{a}_j$ that distract from P_i. An action a_j either belongs to S_i, to D_i or exerts no influence on P_i.

The gains between improvement actions and performances cannot generally be quantitatively identified in complex systems [11][12]. The action-performance relationships model may be purely qualitative: an arc “$a \overset{+}{\rightarrow} P$” (resp. “$a \overset{-}{\rightarrow} P$“) indicates that action a improves (distracts from) performance P.

When the influence of actions may be more precisely characterized, a fuzzy relationships model between actions and performances is introduced as proposed in Felix [7][8]. In this latter case, for any performance P_i, S_i and D_i represent fuzzy sets. A set S_i (resp. D_i) contains actions with a positive (resp. negative) influence on elementary performance P_i and δ_{ij}^s (resp. δ_{ij}^d) is the degree of this positive (resp. negative) influence. $\forall i, j, \delta_{ij}^{*} \in]0,1]$, '*' means s or d (see example in Fig. 1) .

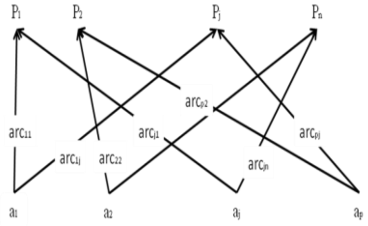

Fig. 1: Influence graph example - Fuzzy model

Let us define the fuzzy membership functions for S_i and D_i [7].

1) Support function for performance P_i :

$s_{P_i}(a_j) = \delta_{ij}^{s} \Leftrightarrow$ action a_j influences P_i positively (supports P_i) with degree δ_{ij}^{s} , 0 otherwise.

2) Distraction function for performance P_i :

$d_{P_i}(a_j) = \delta_{ij}^{d} \Leftrightarrow$ action a_j influences P_i negatively (distracts from P_i), with degree δ_{ij}^{d} , 0 otherwise.

For each performance P_i , the two fuzzy sets S_i and D_i are then defined by s_{P_i} and d_{P_i} values.

2.2. Influence of an action plan

Action plans are to be assessed and compared in our problematics, thus a basic idea consists in attributing an overall score to an action plan from the influence model above. This subsection provides a possible computation of this score [11][12].

2.2.1 Aggregated influence degree

A score is attributed to a subset of actions proposal from the fuzzy values δ_{ij}^{*} restricted to actions in $A(m_l)$.

Let AP_J be an action plan. J refers to the subset of indices for actions in AP_J . For a given performance P_i , J_i^{+} refers to the subset of indices for actions in $AP_J \cap S_i$, and J_i^{-} refers to the subset of indices for actions in $AP_J \cap D_i$.

The proposed idea is to compute how influential an action plan AP_J is. First, let us remark that δ_{ij}^{*} cannot generally be defined with a cardinal scale in industrial practical cases. Thus, they are only considered as an ordinal scale. The higher the impact δ_{ij}^{s} (resp. δ_{ij}^{d}), the higher the improvement (resp. damage) with regards to P_i . Then, the influence degree of action plan AP_J with regard to elementary performance P_i may be given by:

$$\forall i, s_{P_i}(AP_J) = \min_{j \in J_i^{+}} \delta_{ij}^{s} \text{ when } \min_{j \in J_i^{+}} \delta_{ij}^{s} > \max_{j \in J_i^{-}} \delta_{ij}^{d}, \quad \text{else } 0 \quad (1)$$

Hence, an improvement action plan AP_J improves performance $i \in C*$ with degree $s_{P_i}(AP_J)$ if $s_{P_i}(AP_J) > 0$. Eq.(1) is a mere example of aggregation, it is a rather severe behavior from a practical point of view, but this point is not the concern of the paper.

Definition 1: Incompatible actions

Two actions a_j and $a_{j'}$ are said to be *incompatible* w.r.t a performance i if the improvement degree of a_j (resp. $a_{j'}$) on i is lower than the distract degree of $a_{j'}$ (resp. a_j) on i.

Corollary: If two incompatible actions a_j and $a_{j'}$ w.r.t i belong to a subset AP_J then $s_{P_i}(AP_J) = 0$.

Definition 2: A subset of improvement actions or partial action plan AP_J is α-admissible relatively to a non empty subset of criteria $C \subseteq C^{*}$ if it improves all the criteria in C at least with degree α , there are no incompatible actions in AP_J w.r.t any criterion in $C^{*} \setminus C$ and $\sum_{j \in J} c(a_j) \le B$ (where B is the maximal allocated budget and $c(a_j)$ the cost of action a_j). The admissibility degree of AP_J is defined by:

$$s_C(AP_J) = \min_{i \in C} s_{P_i}(AP_J) \quad (2)$$

Practically, AP_J is said to be admissible if there exists $\alpha > 0$ such that AP_J is α -admissible relatively to C^{*} .

The choice of the operators in formula (2) leads to a form of veto upon any performance criterion. Thus, it models a cautious viewpoint regarding the lack of knowledge on the importance of each elementary performance to the overall one. Of course other less constraining operators could be envisaged in (1) and (2).

Definition 3: A subset of actions AP_{J_1} is *consistent* with an action plan AP_{J_2} that is α -admissible relatively to $C \subseteq C^{*}$ if $AP_{J_1} \cup AP_{J_2}$ is an α -admissible action plan relatively to $C' \supset C$.

2.2.2 Related consistency properties

As the improvement action plan that the departments collectively build must respect constraints concerning the influence degree (at least $\alpha \in]0,1]$) and the cost (not greather than B), it is obvious that the subset of actions proposed by a department must satisfy the following properties.

Property 1: Restricting actions elimination

- If there exist i in $C*$ and an action a_j such that $s_{P_i}(a_j) < \alpha$ then a_j is an admissibility restricting action which must be eliminated.
- If $c(a_j) > B$ then a_j is a cost restricting action which must be eliminated.

Property 2: Locking actions elimination

If there exist i in C^{*} and an action a_j such that a_j distracts from P_i with a degree δ_{ij}^{d} greater than any δ_{ik}^{s} , with a_k in the subset of available actions. Then a_j is a locking action which must be eliminated.

Note that a locking action a_j cannot be diagnosed by the owner of a_j himself: all the other departments must report that they cannot compensate the damaging effect of a_j.

3. Argumentation framework of the negotiation

In [6], Dung provides a theory of acceptability of arguments and shows the fundamental role this theory can play in investigating the logical structure of many social and economic problems. Some definitions are remembered in this section. The model that is introduced here is largely inspired from Dung's theoretical argumentation framework [6].

Definition 4: An argumentation framework is a pair $AF = \langle A, R \rangle$ where A is a set of arguments and $R \subset A \times A$ is an attack relation. An argument $\arg_1$ attacks an argument $\arg_2$ *iff* $(\arg_1, \arg_2) \in R$. By extension, a set of arguments S attacks arg if arg is attacked by any element of S.

When analyzing the attack relation, the aim is to find the set of arguments that would win out in a controversial decision, *i.e.*, a subset of arguments that are robust against attacks. A robust set is called an extension. Several extensions may be envisaged [6]. Some necessary definitions from [6] are provided in the following.

Definition 5: A set S of arguments is said to be conflict-free if there are no elements $\arg_1, \arg_2 \in S$ such that $(\arg_1, \arg_2) \in R$.

Definition 6: (1) An argument $\arg_1 \in A$ is acceptable with respect to a set S of arguments *iff* for each argument $\arg_2 \in A$: if $(\arg_2, \arg_1) \in R$ then $\arg_2$ is attacked by S.
(2) A conflict-free set of arguments S is admissible *iff* each argument in S is acceptable w.r.t S.

Definition 7: A preferred extension of an argumentation framework AF is a maximal (w.r.t set inclusion) admissible set of AF.

Definition 8: A conflict-free set of arguments S is called a stable extension *iff* S attacks each argument which does not belong to S.

The existence of a preferred extension which is not stable indicates the existence of some "anomalies" in the corresponding argumentation framework.

Definition 9: An argumentation framework AF is said to be coherent if each preferred extension of AF is stable.

In section 4, this theory is now instantiated to the collective search of an improvement action plan for all criteria in C^*. In section 5, the argumentation framework is then proposed to manage the interactions between arguments in case of conflicts (attack relation). A coherent argumentation framework is designed and it is shown that its stable extension is the set of arguments whose related actions form a sufficient subset improving all criteria in C^*.

4. Knowledge representation in the debate

In this section, a representation of departments' knowledge to design performances improvement is provided. A piece of knowledge is assimilated to a rule which necessarily includes an action, the criteria this action impacts on, the sign of the influence (damage '-' or improvement '+') and the exact or estimated value of this influence (see Fig. 1). Indeed, if the action belongs to $A(m_l)$ then department m_l knows the exact influence of his own actions (at least their qualitative influences (δ_{ij}^* values) *e.g.*, the production department claims that a predictive maintenance *weakly, significantly, strongly* improves the *rejects rate*). If it does not belong to $A(m_l)$, m_l has to estimate the value of the influence from the debate's evolution. This rule is depicted by a subset of arcs (see example in Fig. 1).

4.1. Knowledge bases

Let note K_l the knowledge base of m_l, only rules with actions in m_l initially belong to K_l. K_l then evolves over time with the debate's progress and the current submitted action plan SAP : m_l learns lower or upper bounds for δ_{ij}^* values, for any $a_j \in SAP \cap A(m_{l' \neq l})$ from the debate. Hence, K_l is a set of knowledge φ that can be stated as follows:

- $\varphi =: a_j \wedge (a_j \overset{\lambda_{ij}^s(l)}{\underset{+}{\rightarrow}} P_i)$, *i.e.*, a_j supports an improvement of P_i with a degree $\delta_{ij}^s(l) \geq \lambda_{ij}^s(l)$ when $a_j \in A(m_{l' \neq l})$ (because of formula (1), m_l cannot know the exact influence of such action proposed by $m_{l' \neq l}$) ; with a degree $\delta_{ij}^s(l) = \lambda_{ij}^s(l)$ when $a_j \in A(m_l)$;
- $\varphi =: a_j \wedge (a_j \overset{\lambda_{ij}^d(l)}{\underset{-}{\rightarrow}} P_i)$, *i.e.*, a_j distracts from P_i with a degree $\delta_{ij}^d(l) \leq \lambda_{ij}^d(l)$ when $a_j \in A(m_{l' \neq l})$; with a degree $\delta_{ij}^d(l) = \lambda_{ij}^d(l)$ when $a_j \in A(m_l)$.

In other words, each department is supposed to know the subgraph structure related to any action as soon as it is proposed. However, he does not necessarily know the exact influence of actions of other departments in the current action plan (i.e., the exact values of the graph parameters for $a_j \notin A(m_l)$). During the debate, departments' knowledge evolves: the arguments that are exchanged can make the identification of the gain of the action-goal relationship gradually more accurate. Each department learns from the discussion.

4.2. Arguments

Only decision arguments are distinguished in this approach, *i.e.*, knowledge that conclude in favor of (against) an alternative w.r.t the objectives in C^*.

A set of knowledge $\varphi =: a_j \wedge (a_j \underset{\pm}{\overset{\delta_{ij}^*}{\rightarrow}} P_i)$, $j \in J$ and $i \in C' \subseteq C^*$ is said to be an argument, denoted *arg*, of department m_l, if the subset of actions $AP_J \subseteq A(m_l)$ is consistent with the current subset of improvement actions SAP (α-admissible relatively to a subset of criteria $C \subseteq C^*$) built by the collective beforehand. It is denoted: $\arg =: \langle AP_J \wedge (SAP \cup AP_J \underset{+}{\overset{\alpha}{\rightarrow}} C' \supset C)\rangle$.

Example of argument: $C^* = \{P_1, P_2, P_3, P_4\}$, $\alpha = 0.6$ and $SAP = \{a_1, a_2, a_3\}$ is a subset of improvement actions, with $C = \{P_1, P_2\}$ (see Fig. 2).

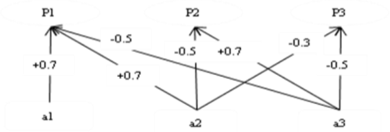

Fig. 2: an example of partial action plan

Fig.2 shows the qualitative influences of SAP. A department m_l may then propose argument $\arg =: \langle AP_J \wedge (SAP \cup AP_J \underset{+}{\overset{\alpha}{\rightarrow}} C')\rangle$, where $AP_J = \{a4\}$ is consistent with SAP, $C' = \{P_1, P_2, P_3\}$ and the associated knowledge base is for example: $\varphi =: a_4 \wedge (a_1 \underset{+}{\overset{0.7}{\rightarrow}} P_3)$, $\varphi =: a_4 \wedge (a_4 \underset{-}{\overset{0.4}{\rightarrow}} P_4)$.

5. The debate structure

This section explains how to build an action plan for all criteria in $C*$ from the debate between departments.

5.1. General principle

Once all departments know the amount B granted by the direction to the improvement project and the required admissibility degree α, one department proposes some of his actions, he claims to improve a subset of performances and thus partially contributes to the collective improvement objective. Nevertheless, these actions may distract from some other performances. Each time additional actions are proposed, departments have then to update their knowledge base by suppressing their restricting actions.

Let us introduce time variable t explicitly in the notations. Let $SAP(t)$ be the current improvement action plan built by the departments at time *t*. At ($t = 0$): $SAP(0) = \varnothing$. The debate organization is broken down into the following steps:

- Each department computes arguments $AP_J^{m_l}(t)$, *i.e.*, sub action plans consistent with $SAP(t-1)$ and adopts a suitable strategy (see subsection 5.2.2) to make a proposal among these arguments to maximize his earnings when possible;
- Let $D(t)$ be the set of the preferred action plan of each department at step *t* (one argument by department). A preference relation on $D(t)$ is introduced to select the department m_s who will be the next speaker in the debate (see subsection 5.2.1). The two following situations are to be distinguished:

  -1- If $D(t) \neq \varnothing$: action plans can still be proposed; the new proposal contributes to increase the number of improved performances, it is a *constructive* argument;

  -2- If $D(t) = \varnothing$ then no sub action plan consistent with $SAP(t-1)$ can be proposed. In consequence, any other proposal added to $SAP(t-1)$ would imply cost or admissibility conflicts. This situation is a deadlock. This case is associated to an *attack* argument: the next additional proposal attacks previous proposals and any department having actions in $SAP(t-1)$ which are attacked must withdraw them (see subsection 5.3).

  In both situations the new proposal allows adjusting and updating other departments' knowledge for revision purposes (see subsection 5.4).

Furthermore, once an argument is chosen, if the sub action plan associated to the argument contains any *locking* action (other departments declare to be unable to compensate them), this action is removed from the proposal and the owner department cancels it from his own knowledge base.

At each step *t*, the subset of improvement actions can be stated as: $SAP(t) = \bigcup_{k=0}^{t} AP_J^{m_l}(k)$. The debate ends when $SAP(t)$ improves all criteria in $C*$ under required admissibility and cost constraints or when no more action is available and no solution is found.

In the following sections (5.2 to 5.4) the steps of the debate are presented in detail.

5.2. Selection of action plans

5.2.1. Fair resources sharing

Let $G_l^{\max} = \sum_{a \in A(m_l)} c(a)$ be the maximal expected gain for department m_l and $G_l(A_J) = \sum_{a \in A_J \cap A(m_l)} c(a)$ be the individual gain of department m_l from a subset of improvement actions A_J. $G_l^{\max} - G_l(A_J)$ is then the loss of earnings for m_l w.r.t A_J. For homogeneity reasons, formula $r(l, A_J) = (G_l^{\max} - G_l(A_J)) / G_l^{\max}$ is preferred to characterize the relative loss of earnings for any department m_l w.r.t A_J.

In this paper, we consider that the group tries to avoid an unfair sharing of the allocated budget by minimizing the loss of earnings of the worst paid agent. This behavior can be captured in criteria such that $\min_{A_J} \max_l r(l, SAP(t))$ or $\min_{A_J} \sum_l r(l, SAP(t))$ [10]. Let denote:

$\forall AP_J \in D(t),\ lewp(AP_J) = \max_l r(l, SAP(t-1) \cup AP_J)$,

then $\arg\min_{AP_J \in D(t)} lewp(AP_J)$ is selected as the next proposal in the debate.

Considering the set of departements having proposition at time t, This criterion points out the department with the most injured party relatively to the current action plan $SAP(t-1)$ to make the next proposal $AP_J^{m_s}(t) \subseteq A(m_l)$: thus $SAP(t)$ includes actions of m_l and increases his earnings.

5.2.2. Individual action plan choice strategies

At each step *t*, all the departments with available arguments must adopt an appropriate strategy to propose the most relevant argument for their department. A department m_l may locally use a branch and bound algorithm with $A(m_l)$ to find the most relevant argument he may propose (subsets A_J consistent with $SAP(t-1)$). The following criteria may be introduced depending on the debate stage:

- $AP_J^{m_l}(t)$ may maximize the number of improved criteria when possible, *i.e.*, there is no admissibility or cost conflict (constructive arguments);
- $AP_J^{m_l}(t)$ may maximize the admissibility of his proposal in case of admissibility conflict (definition 10) (attack arguments);
- $AP_J^{m_l}(t)$ may minimize the cost of his proposal in case of cost conflict (definition 11) (attack arguments).

Finally, $D(t) = \{AP_J^{m_l}(t), 1 \le l \le M\}$ where J may be empty for some departements.

5.3. Attack relation

As soon as arguments are modeled by rules, it is clear that an argument attacks another one if their conclusions are in conflict or if the conclusion of one of them refutes the premises of the second one [1][6]. Let us introduce the following definitions concerning conflicts.

When $SAP(t-1)$ fulfills criteria in $C \subset C^*$ and $D(t) = \emptyset$ then no sub action plan consistent with $SAP(t-1)$ can be proposed. In consequence, any other proposal added to $SAP(t-1)$ implies cost or admissibility conflicts. Actions at the origin of the debate deadlock are to be removed from $SAP(t-1)$. Hence, next argument must first attack arguments supporting $SAP(t-1)$.

Definition 10: $D(t) = \emptyset$. Two sub action plans $AP_{J_1}(t)$ and $AP_{J_2}(t' < t) \subseteq SAP(t-1)$ are said to have *admissibility conflict* w.r.t criterion i if there exist at least two actions $a_j \in AP_{J_1}(t)$ and $a_{j'} \in AP_{J_2}(t')$ that are *incompatible* w.r.t i (definition 1).

Definition 11: $D(t) = \emptyset$. Two sub action plans $AP_{J_1}(t)$ and $AP_{J_2}(t' < t) \subseteq SAP(t-1)$ are said to have *cost conflict* w.r.t criterion i^c if $AP_{J_1}(t)$ and $AP_{J_2}(t')$ improve i^c whereas i^c is related to the costliest improvement actions.

Hence, the following attack relation is introduced.

Definition 12: there is an attack relation R between two arguments $\arg_1 =: \langle AP_{J_1}(t) \wedge (SAP(t) \overset{\alpha}{\underset{+}{\rightarrow}} C') \rangle$ and $\arg_2 =: \langle AP_{J_2}(t' < t) \wedge (SAP(t-1) \overset{\alpha}{\underset{+}{\rightarrow}} C) \rangle$, if $D(t) = \emptyset$ and $AP_{J_1}(t)$ is in admissibility ($C' \cap (C^* \backslash C) \ne \emptyset$) or cost ($C' \supset \{i^c\}$) conflict with $AP_{J_2}(t')$.

5.4. Knowledge sharing for collective purpose

Let m_l the departement owner of the next proposal $AP_J^{m_l}(t) \subseteq A(m_l)$. Since departments $m_{l' \ne l}$ a priori don't know influences of actions in $A(m_l)$, they have to learn from the discussion. m_l will then indicate the new digraph structure and the updated influences as follows.

If the department m_l starts the debate, he provides the exact influences of $AP_J^{m_l}(t=1)$ on each performance P_i influenced by $AP_J^{m_l}(1)$. Then $\forall l', \forall j \in J, \forall i \in C^*$, $\delta_{ij}^s(l') = \delta_{ij}^s(l)$ and all the departments will deduce the minimal positive influence denoted $\min_i^+(1)$ (or the maximal negative one denoted $\max_i^-(1)$) regarding P_i influenced by $SAP(1) = AP_J^{m_l}(1)$.

At each time $t > 1$, $\min_i^+(t)$ and $\max_i^-(t)$ are computed: let $AP_J^{m_l}(t) \subseteq A(m_l)$ the sub action plan added to $SAP(t-1)$. If $\exists a_j \in AP_J^{m_l}(t)$ and $i \in C^*$ such that $\delta_{i,j}^s < \min_i^+(t-1)$ (resp. $\delta_{i,j}^d > \max_i^-(t-1)$) then m_l must provide the exact influence of a_j which updates $\min_i^+(t)$ (resp. $\max_i^-(t)$).

As $AP_J^{m_l}(t)$ is consistent with $SAP(t-1)$, departments $m_{l' \ne l}$ may infer the influence bounds $\lambda_{i,j}^s$ and $\lambda_{i,j}^d$ (see subsection 4.1) of any action in $AP_J^{m_l}(t)$ on each P_i by using formula (1) as follows: $\lambda_{i,j}^s = \min_i^+(t)$ and $\lambda_{i,j}^d = \max_i^-(t)$.

When $AP_J^{m_i}(t)$ attacks arguments in $SAP(t-1)$ (see 5.3) then actions are removed from $SAP(t-1)$ and departments having the new maximal damage or the new minimal improvement on a criterion must declare these new reference values. This allows other departments to readjust their knowledge.

Departments are supposed to be cooperative, *i.e.*, only relevant and useful arguments are exchanged to achieve a consensual action plan and a convenient solution cannot be dismissed for only personal purposes.

5.5. Admissible action plan and coherence of the argumentation framework

Suppose $SAP(t)$ is built as described above and improves all criteria in C^*. Then, $SAP(t)$ is a solution that concludes the collective search of improvement action plans.

Let A be the set of all arguments that departments have proposed in the debate: the ones in $SAP(t)$ and all the arguments that have been removed by attacks during the debate. Let consider the argumentation framework $AF = \langle A, R \rangle$ with R the attack relation defined in subsection 5.3. Let S be the set of all arguments whose related actions are in $SAP(t)$ and $S' = \{\arg \in A \setminus S \,/\, \nexists \arg' \in S, (\arg', \arg) \in R\}$ (S' is the set of arguments in $A \setminus S$ that are not in conflict with arguments in S). Indeed, such subset S' may exist: suppose action $a_j \in SAP(t_1)$; then, an argument supporting a_j has been attacked by a new argument arg at time t_2 $(t_1 < t_2 < t)$; later, at time t_3 $(t_2 < t_3 < t)$, this argument has been attacked in turn. Hence, $a_j \in A \setminus S$ but it is not necessarily attacked by S.

Property 3: S is an admissible set of arguments (in the sense of Dung, definition 6) *iff* $SAP(t)$ is an admissible action plan (definition 2).

Property 4: $\exists S'' \subset S' / S \cup S''$ is a preferred extension of AF.
In other words, preferred extensions including S can be built but the subset of actions they support is costlier than $SAP(t)$.

Property 5: Any preferred extension $S \cup S''$ of AF is stable and thus AF is coherent.

6. Simulation

The study case concerns a simple manufacturing factory.

The overall objective of the company is to increase its customer satisfaction. On one hand, four criteria are identified by the company to capture this overall performance w.r.t customers' satisfaction: *Range of Products (P1), Products pricing (P2), Products Quality (P3)* and *Time delivery (P4)*. They are completed with an internal criterion: *Social Climate (P5)*. On the other hand, actions correspond to the setting up of industrial performance improvement methods (the detail of actions cannot be developed here for obvious paper length reasons). Actions are denoted $a_{j=1..11}$. They are supposed to have the same cost $(\forall a_j, c(a_j)=1)$. The improvement project must be carried out by three departments who have to share and respect the budget granted by the direction. In the simulation, it is supposed that: $A(m_1)=\{a_1,a_2,a_3,a_4\}$, $A(m_2)=\{a_5,a_6,a_7\}$ and $A(m_3)=\{a_8,a_9,a_{10},a_{11}\}$. The action-goal relationships graph is provided in Table 1. Items of the matrix provide the δ_{ij}^* values.

P	Department1				Department2			Department3			
	a1	a2	a3	a4	a5	a6	a7	a8	a9	a10	a11
P1	-.2	.9		-.3	-.2	.3	-.4	.9	-.6	-.2	-.5
P2	.8	.2	.3	.6	.9			-.5	.7	.8	.8
P3	.5	.5	.8	.2	-.3	.8	.7			.2	-.3
P4	-.2	-.5	-.5	.5	.1		.6	-.55	.9	.3	
P5		.6	.7	-.4		.4	.7		.5	-.3	-.4

Table 1: Action-goal relationships matrix

In previous works, when all action-goal relationships are supposed to be known by each department, we have developed a global branch and bound algorithm to compute a set of non-dominated admissible action plans AP for the couple $(s_{C^*}(AP), -c(AP))$ (*i.e.*, admissibility degree and cost) in the sense of *pareto*:

$$(\theta,\vartheta) \prec_{Pareto} (\theta,\vartheta) \Leftrightarrow (\theta<\theta' \text{ and } \vartheta \le \vartheta') \text{ or } (\theta=\theta' \text{ and } \vartheta<\vartheta')$$

Fig. 3 presents the set of non-dominated admissible action plans AP provided by the branch and bound algorithm.

(Admissibility,-Cost)	(0,2 , -2)	(0,5 , -3)
Subset of Actions	{a10 , a6}	{a1 , a8 , a9}
	{a2 , a7}	
	{a2 , a9}	

Fig. 3: optimal results achieved from the branch and bound algorithm

We have then developed a software tool that supports the method depicted in this paper in order to simulate an argumented negotiation between departments.

It is applied here to the study case. The result of the deliberation depends on the first department speaking. Let us suppose $\alpha = 0.2$ and budget $B=4$. When department 3 starts the negotiation, he first proposes $AP_{J_1} = SAP(1) = \{a_9, a_{10}\}$ to maximize his earnings and improve criteria in $C=\{P_2,P_3,P_4,P_5\}$ (see Fig. 4 - $\min = 1.1$ simply means by convention that no improvement is provided regarding the related performance, $\max = 0$ means there is no damage on the related performance). As $D(2)=\varnothing$, department 1 states his argument associated to $AP_{J_2} = \{a_2\}$ to attack the argument supporting AP_{J_1} due to an admissibility conflict on criterion 4. As consequence, action a_{10} is removed from $SAP(2)$ (see Fig. 5).

In this case, the solution provided by the debate is one of the optimal solution $\{a_2, a_9\}$ resulting from the global branch and bound algorithm. It is not always the case for multiple reasons: first, the objective of both approaches is not the same since each department not only tries to contribute to the overall objective under cost constraints but also tries to maximize his own earning in the argumented negotiation approach. Secondly, departments propose a solution that merely respects admissibility and cost constraints in the argumented negotiation approach. It is generally a mere suboptimal solution. However optimality is not revealed to the executive board of the company… That is the bounded rationality effect in organizational decisions.

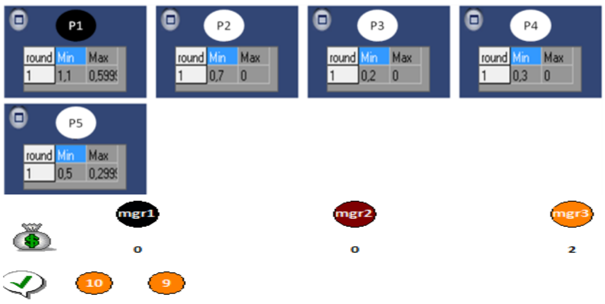

Fig. 4: situation *(t=1)* when mgr3 starts the debate – actions and their related department circles have the same color

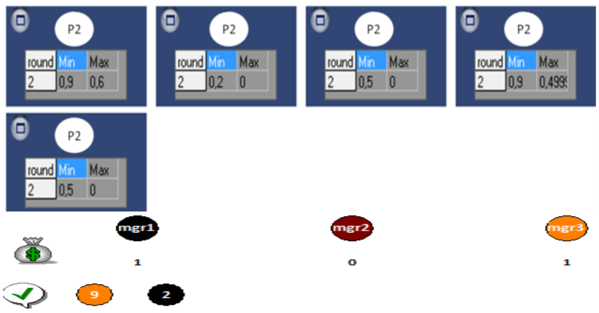

Fig. 5: situation (*t=2*) after mgr1 attacks mgr3 and provides a solution (*cost*=2, *mgr1* and *mgr3* earning is equal to 1)

7. Conclusion

This paper has proposed a decision support system to help departments collectively designing an action plan to improve performances of their company. An argumentation framework has been proposed to manage conflicts of interests between cooperative agents. It allows simulating argumented negotiations and thus provides a relevant decision-support system for complex improvement project.

The debate simulation is of interest for various purposes:

- It is an alternative to global optimization;
- It may also be envisaged as a decision-support system by a particular department;
- It may be used as a support system for explanation or control of the debate evolution.

Lots of criteria have been introduced for action plans selection (minimizing the loss of earnings, admissibility aggregation operator, …). They provide a globally rational model that allows solving a large class of problems. This class of problem may be enlarged by providing other criteria with new semantics. This is the concern of our futur works. Finally, only basic notions of argumentation theory have been used in this model, more complex frameworks like contextual preference-based argumentation frameworks could be introduced in our work to model the evolutive set of arguments [5].

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