

INFORMATION TRANSFER STRATEGIES OR HOW TO REACH EQUILIBRIUM AND CONTROL IN DIRECT VERBAL COMMUNICATION

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This article focuses on identifying the means by which communication based interactions can generate wins in order to make direct verbal communication, like debates, more efficient. Communication optimization consists in designing and formally employing a mathematical model that can lead to qualitative equilibrium and subsequently to gaining an advantageous position in two way communication instances.

Key words: *communication, optimization, random strategies, entropy.*

1. INTRODUCTION

The concept of “information” acquires various meanings depending on the perspectives that define it, as well as on the goals it serves. Generally speaking, information transfer requires two parties involved in the process of exchange incurred by communication instances.

The idea of random interaction as part of open communication is to a certain extent formalized by Game theory. As Silviu Guiaşu stated back in 1973, random games among n parties are “*one of the first non-trivial examples of reverse based connection systems*”, a statement that obviously indirectly referred to cybernetics

[1]. Even though the concept has evolved, what it basically refers to is communication based interaction anchored into numerous means and techniques to express an intended message in a certain sequence and employed by entities that are present in a communicational environment. Communication structures are built on rules that, even if they are a priori established, they meet the contextual communication needs of the parties involved in the process which may be aligned, may be different or completely contradictory. A system that delivers verbal information in a competition based environment has its own constitutive elements.

Moreover, the mutual dependencies and connections make the relations that underpin the elements of an information system as a result of its evolution.

According to the mathematical theory of information and based on a broad definition of the concept, the process of conveying information is considered a random one. Communication among human beings, regardless of its type, is generated by specific goals and reasons. Consequently, the party delivering a message also becomes part of that is called "persuasion tendency".

In order to reach its goal, the entity conveying the message needs to adopt, depending on the context, a certain communication strategy. The latter actually offers the possibility to qualitatively analyze the content of vocal communication in a competition based environment. This study is to focus on the means by which in a two way communication process the transfer of information can reach a qualitative equilibrium, as well as on identifying the manner in which one can gain control in direct communication instances. The types of interactions of interest for this paper are the non-collaborative ones in which an entity conveying a message does not a priori know the intentions and resources of its communication partners. Moreover, another aim is to quantify the advantage that a participant to the communication instance who is also the message transmitter also

gains in a communication process as a result of employing random communication strategies based on entropic optimization.

2. RANDOM INTERACTION STRATEGIES AND THEIR ROLE IN ACHIEVING EQUILIBRIUM IN DIRECT COMMUNICATION

For any $i=1,2,\dots,n$ we call the formula $S_i = \{S_i^1, S_i^2, \dots, S_i^j\}$ information partition of the i communication initiator. We note by F_i the *win formulas* of message initiators. An individual communication initiator's plan related to the communication interaction is called *individual strategy*. Thus, an i initiator's individual strategy in the Δ interaction is an x_i map defined as S_i that associated to any S_i^j information lot a unique value from the indexing lot. Hence, the **strategy B** signifies an initiator's means of expression that the latter is ready to use for any circumstances that may ensue in the communication process. An $\bar{x} \in X$ strategy is a point of equilibrium for the Δ interaction, if for any $i = 1, 2, \dots, n$,

$$F_i(\bar{x}) \geq F_i(\bar{x}_1, \bar{x}_2, \dots, \bar{x}_{i-1}, x_i, \bar{x}_{i+1}, \dots, \bar{x}_n) \quad (1)$$

regardless of what the $x_i \in X_i$ strategy is.

Any communication initiator's desirable goal is to maximize the chances of having their own opinion prevail. Nonetheless, since the other communication parties' interests are generally different it seems that a

situation in which all entities involved in the communication process reach their own goals is unlikely. If a point of equilibrium were to be reached in the interaction, then that could provide the means by which neither communication initiator is at disadvantage or at advantage.

By transcribing (1) for the particular case on an interaction among two initiators $\Delta=\{X,Y,F\}$ it results that a (\bar{x}, \bar{y}) strategy of the interaction is a **point of equilibrium** if the following inequalities are satisfied:

$$\begin{aligned} F(\bar{x}, \bar{y}) &\geq F(x, \bar{y}), \forall x \in X \\ -F(\bar{x}, \bar{y}) &\geq -F(\bar{x}, y), \forall y \in Y \end{aligned} \quad (2)$$

which generates the double inequality:

$$F(x, \bar{y}) \leq F(\bar{x}, \bar{y}) \leq F(\bar{x}, y) \quad \forall x \in X, y \in Y \quad (3)$$

According to the Karuch-Kuhn-Tucker conditions, a point of equilibrium for the Δ interaction is a saddle point for the win formula F [2]. The meaning of this result, namely of the term ‘saddle point’ is revealed by the answer to the question: ‘What does an optimum means of expression signify in the case of both initiators of interaction Δ ?’. If, for example, the first initiator chooses an x personal strategy, the latter can only be ‘a priori’ certain of the win given by:

$$\min_{y \in Y} F(x, y) \quad (4)$$

In such a case, the optimum of his communication is reflected in the choice of a $\bar{x} \in X$ strategy that

allows for gaining the maximum from previous wins:

$$w_1 = \min_{y \in Y} F(\bar{x}, y) = \max_{x \in X} \min_{y \in Y} F(x, y) \quad (5)$$

That is actually the Max-Min principle that governs game theory in terms of the optimum criterion that guides the choice of the means of action. In our case, this principle represents the performance criterion in terms of choosing the optimum means of expression in competition based communication. If the previous inference which has the win function $-F$ is repeated from the perspective of the second initiator, the same Max-Min principle will determine the latter to adopt the $\bar{y} \in Y$ strategy that grants him the chance of a win of at least:

$$\begin{aligned} -w_2 &= \min_{x \in X} (-F(x, \bar{y})) = \max_{y \in Y} \min_{x \in X} (-F(x, y)) = \\ &= -\min_{y \in Y} \max_{x \in X} F(x, y) \end{aligned} \quad (6)$$

In such a case, the gain of the first initiator is maximum:

$$w_2 = \min_{y \in Y} \max_{x \in X} F(x, y) \quad (7)$$

The w_1 and w_2 terms are called the ‘max-min value’, and the ‘min-max value’ between which there is the following relation: $w_1 \leq w_2$. In the special case in which $w_1 = w_2 = w$, then $\bar{x} \in X$ and $\bar{y} \in Y$ so that:

$$F(x, \bar{y}) \leq w \leq F(\bar{x}, y) \quad (8)$$

Regardless of $x \in X$ and $y \in Y$, and:

$$w = F(\bar{x}, \bar{y}) \quad (9)$$

The value of interaction was noted as w . In such a case, the viceversa

is possible and is a necessary and sufficient condition for:

$$\max_{x \in X} \min_{y \in Y} F(x, y) = \min_{y \in Y} \max_{x \in X} F(x, y) \quad (10)$$

And for the F function to accept a saddle point. If (\bar{x}, \bar{y}) is a saddle point of F, then:

$$F(\bar{x}, \bar{y}) = w \quad (11)$$

and w is the common value of the two members of the previous equality. The result actually expresses the fact that in a communication stance involving two initiators, the point of equilibrium is rendered by the max-min strategies of the two. The concept of strategy in the communication process can extend given the non-determinate character of the means of expression of information message initiators. A random strategy of the communication instance Δ is a pair of random strategies of the two initiators. The lot of this strategies is noted as S_a . The interaction Δ is also defined by the **win matrix** $\Phi=(\phi_{ij})$, $1 \leq i \leq m$, $1 \leq j \leq n$. That includes in the case of the communication process the values of the vocal and acoustic parameters, the prosodic and emotional features, as well as the elements that derive from the content and style of composing the spoken texts.

A random strategy of the A initiator can be considered under the random m-dimensional vector $\sigma_1=(p_1, p_2, \dots, p_m)$,

$$p_i \geq 0, \sum_{i=1}^m p_i = 1$$

A random strategy of the B initiator can be considered under

another random n-dimensional vector $\sigma_2=(q_1, q_2, \dots, q_n)$,

$$q_j \geq 0, \sum_{j=1}^n q_j = 1$$

Given the decreased level of predicatability of the wins that the two initiators can obtain, we can only mention the *average* win of A or B. For example, for the A initiator, the average win is:

$$F_m(\sigma_1, \sigma_2) = \sum_{i=1}^m \sum_{j=1}^n \alpha_{ij} p_i q_j \quad (12)$$

A result that confirms the existence of a point of equilibrium in the case on communication interactions is the min-max theorem of von Neumann: *'Any matrix based interaction accepts at least one point of equilibrium consisting of random strategies'* [3]. In this context, we would like to increase the level of generality of a communication process by considering the case of non-collaborative communication interaction of variable sum between two initiators, this type of interaction does not necessarily involve the existence of contradictory interests. It can be the case of verbal communication in the form of debate, dialogue and not in the form of direct competition based interaction. Even if in such a case the interests of the interlocutors are considerably different, the rule according to which the win of an initiator triggers a diminished win for the other does not manifest. The attitude of both communication partners is rather indifferent; each of them focuses on one's own advantage [4]. The point

of equilibrium concomitantly grants the interaction partners a relative maximum win; if A adopts the (\bar{x}) strategy, B cannot obtain more than the (\bar{y}) strategy can grant, and vice versa.

All of the above considered, the (\bar{x}, \bar{y}) strategy of a Δ interaction, of a variable sum, between two initiators is a point of equilibrium according to the inequalities:

$$F_1(\bar{x}, \bar{y}) \geq F_1(x, \bar{y}); F_2(\bar{x}, \bar{y}) \geq F_2(\bar{x}, y) \quad (13)$$

for any $x \in X$ and $y \in Y$.

In particular, in the bi-matrix interaction Δ with the win matrices $A=(\alpha_{ij}), B=(\beta_{ij}), 1 \leq i \leq m, 1 \leq j \leq n$, the pure strategy (i_0, j_0) is a point of equilibrium if:

$$\alpha_{i_0 j_0} \geq \alpha_{i_0 j}, \beta_{i_0 j_0} \geq \beta_{i_0 j}; i=1, 2, \dots, m; j=1, 2, \dots, n \quad (14)$$

In the same formalized context, we introduce the functions of average win forecasted by the two partners if they adopt the random strategies σ_1 , and σ_2 :

$$F_1(\sigma_1, \sigma_2) = \sum_{i=1}^m \sum_{j=1}^n \alpha_{ij} p_i q_j$$

$$F_2(\sigma_1, \sigma_2) = \sum_{i=1}^m \sum_{j=1}^n \beta_{ij} p_i q_j \quad (15)$$

In this case, Nash's theorem states that 'Any Δ bi-matrix interaction accepts points of equilibrium made of random strategies' [5]. In the context of non-collaborative interactions with variable sum, the wins differ by the different points of equilibrium.

The following result offers the conditions under which a point of equilibrium can be reached, in the context in which win matrices and random strategies are organized.

The pair of random strategies $\bar{\sigma}_1 = (\bar{p}_1, \bar{p}_2, \dots, \bar{p}_m), \bar{\sigma}_2 = (\bar{q}_1, \bar{q}_2, \dots, \bar{q}_n)$ makes a point of equilibrium for the Δ bi-matrix interaction, with A and B win matrices, if and only if for any $i=1, 2, \dots, m$:

$$\sum_{i=1}^m \sum_{j=1}^n \alpha_{ij} \bar{p}_i \bar{q}_j \geq \sum_{j=1}^n \alpha_{ij} \bar{q}_j \quad (16)$$

and for any $j=1, 2, \dots, n$:

$$\sum_{i=1}^m \sum_{j=1}^n \beta_{ij} \bar{p}_i \bar{q}_j \geq \sum_{i=1}^m \beta_{ij} \bar{p}_i \quad (17)$$

If for the A matrix the row vector where the row elements are i is noted as A_i and the column vector, where the column elements are j , is noted as B_j the previous formulas can also be noted as:

$$\bar{\sigma}_1 A \bar{\sigma}_2^T \geq A_i \bar{\sigma}_2^T, i = 1, 2, \dots, m$$

$$\bar{\sigma}_1 B \bar{\sigma}_2^T \geq \bar{\sigma}_1 B_j, j = 1, 2, \dots, n \quad (18)$$

The practical method to determine the points of equilibrium in such cases is to replace inequalities like (18) with a system of inequalities of linear inequalities that can be pretty simple to solve.

3. RANDOM COMMUNICATION STRATEGIES BASED ON ENTROPIC OPTIMIZATION

The discussion below concerns the larger context of a random communication interaction with n initiators of the information message. The communication partners may have common or different interests, or even completely opposite. These partners are noted as E_1, E_2, \dots, E_n and

their lot as Σ , and the lot of random strategies as S_a . communication partners can be also seen as representatives of complete systems of probabilities attached to a well defined lot composed of the means of expression characteristic and explicit of every information initiator. The E_i initiator can express himself as $m_i^{k_j}, 1 \leq k_j \leq n_j$, where there are n_j such expression possibilities, with the $p(m_i^{k_j})$ probability. The latter's strategy represents a random variable with the values rendered by the $m_i^{k_j}$ communication instances and which is noted as:

$$\sigma_i : \left(\begin{matrix} m_i^{k_j} \\ p(m_i^{k_j}) \end{matrix} \right); p(m_i^{k_j}) \geq 0, \sum_{k_j=1}^{n_j} p(m_i^{k_j}) = 1, 1 \leq i \leq n \quad (19)$$

Actually, the above signifies the lot of expression means that an initiator has available along with the probabilities that he can use. A set of successive communication instances formulated by n communication partners can be represented by the vector $(m_1^{k_1}, m_2^{k_2}, \dots, m_l^{k_l}, \dots, m_n^{k_n})$ with the probability $p(m_1^{k_1}, m_2^{k_2}, \dots, m_l^{k_l}, \dots, m_n^{k_n}), 1 \leq k_i \leq n_i, 1 \leq i \leq n$. If to $m_i^{k_j}$ a given importance is associated $u(m_i^{k_j}) = u_i^{k_j}$ then the average information amount supplied by the E_i initiator by adopting the $\sigma_i, 1 \leq i \leq n$ strategy is:

$$\Gamma_{n_i}[u_i; E_i] = - \sum_{k_i} u(m_i^{k_i}) p(m_i^{k_i}) \log p(m_i^{k_i}) \quad (20)$$

namely, the **balanced entropy**. The balanced entropy of the E_i information initiator becomes maximum if and only if the σ_i random strategy adopted by the later follows:

$$p(m_i^{k_i}) = \frac{2^{\frac{\alpha}{u(m_i^{k_i})}}}{e}, 1 \leq k_i \leq n_i \quad (21)$$

where α is the solution to the equation:

$$\sum_{k_i=1}^{n_i} 2^{\frac{\alpha}{u(m_i^{k_i})}} = e \quad (22)$$

where:

$$\left[\max_{x_i} \right] \Gamma_{n_i}[u_i; E_i] = - \frac{1}{e} \left(\alpha - \log e \sum_{k_i} u(m_i^{k_i}) \cdot 2^{\frac{\alpha}{u(m_i^{k_i})}} \right) \quad (23)$$

In a more restricted sense, the importance of the manner of expression can be interpreted as a win or success that can be attributed to the initiator that produces it. In this case, the importance can also be negative, namely if the message expression is inadequate it can lead to loss or insuccess for its initiator, hence to a negative win. The indicator that is analysed in such a case is that of average importance and average gain for a given time period [6].

For a certain partner involved in direct competitive communication for a given time period, we can define the latter's average importance as:

$$U(E_i) = \sum_{k_i=1}^{n_i} \dots \sum_{k_n=1}^{n_n} u^i(m_1^{k_1}, \dots, m_n^{k_n}) p(m_1^{k_1}) \dots p(m_n^{k_n}) \quad (24)$$

Nonetheless, this concept promoted, for the information initiator noted as E_i

Who is in competition or at least in connection with the other partners, adopting a random strategy automatically leads to removing certain uncertainties, namely to obtaining information. Thus, considering the two different

components of importance and information from a quantitative perspective, we can quantify the total average win of a participant in the communication process as:

$$A_i(E_1, \dots, E_n) = U(E_i) + H(E_i), 1 \leq i \leq n \quad (25)$$

The optimal strategy of the E_i initiator for obtaining an average win needs to be:

$$p(m_i^{k_i}) = \frac{1}{e} 2^{\alpha + u_i^{k_i}}, 1 \leq k_i \leq n_i, 1 \leq i \leq n \quad (26)$$

where α is the solution for the equation:

$$\sum_{k_i=1}^{n_i} 2^{u_i^{k_i}} = \frac{e}{2^\alpha} \quad (27)$$

for the notation:

$$u^i(m_1^{k_1}, \dots, m_n^{k_n}) = u^i(m_i^{k_i}) = u_k^i, 1 \leq i \leq n.$$

In this case:

$$A_{i \max}(E_1, \dots, E_n) = \log e - \alpha = \log \left[\sum_{k_i=1}^{n_i} 2^{u_i^{k_i}} \right] \quad (28)$$

If we want to capture the qualitative input from the maximum and the result is:

$$p(m_i^{k_i}) = \frac{2^{\frac{\alpha}{2} + u_i^{k_i}}}{e}, 1 \leq k_i \leq n_i, 1 \leq i \leq n \quad (29)$$

and that is the solution to the equation:

$$\sum_{k_i=1}^{n_i} 2^{\frac{\alpha}{2} + u_i^{k_i}} = \frac{e}{2} \quad (30)$$

and the maximum win is expressed as:

$$A_{i \max}(E_1, \dots, E_n) = \frac{2}{e} \log e \sum_{k_i=1}^{n_i} u_i^{k_i} 2^{\frac{\alpha}{2} + u_i^{k_i}} - \alpha \quad (31)$$

The concepts of importance and advantage generated by adopting random strategies are still

valid even when there is a shift from an information initiator or communication partner to a coalition of initiators, and hence the previous results can be generalized in this context.

4. CONCLUSIONS

Classically speaking, the goal of communication is accomplished through information exchange between a sender and a receiver. Unlike the latter, the dynamic perspective imposed by cybernetics reveals the interactional features of the information outlined in communication. Such features generate emulation given their reactivity at the level of the participants to the communication process. The latter become in their turn message initiators. Moreover, information can also be approached from the perspective of the messages it transmits, the importance of specific communication instances, but also in terms of the result or pragmatic effect of its processing. That is the context in which the context of direct communication in a competition based environment was modeled and adapted through parallelism with elements and concepts characteristic of game theory. Concepts like the win function, importance, random strategies that govern communication interactions have been identified and outlined.

The desirable goal of any communication initiator is to maximize the chances of having one's own opinion prevail in direct

explicit communication stances. The article emphasizes the importance of identifying the mathematical mechanisms, as well as of the possibilities to elaborate solutions that can be implemented in *speech analysis* in order to grasp in real time and via balanced entropy related concepts the maximum win of employing means by which individual communication parameters and procedures can be improved.

Along with the adequate monitoring and control, these solutions that could be put into practice might successfully be used in order to increase the chances of optimally transferring important information messages in competitive environments.

REFERENCES

- [1] Guiasu, S., *Information Theory with applications*, McGraw-Hill New York – Dusseldorf, 1977
- [2] Ben-Tal, A., Nemirovski, A., *Robust convex optimization*, Mathematics of Operations Research, 23(4):769–805, 1998.
- [3] Kuhn, H. W., *Classics in Game Theory*, Princeton University Press, 1997
- [4] Mitran, I., *Asupra unei solutii entropice a jocurilor cooperative*, Studii și Cerc. de Calc. Ec. și Cib. Ec.,3, 1981
- [5] Osborne, M. J., Rubinstein, A., *A Course in Game Theory*, Cambridge, MA: MIT Press, 1994
- [6] Purcaru, I., *Asupra unor măsuri ale organizării unui joc strategic*, Studii și Cerc.Mat.,2, 1983, pp.503-517