Influence in AHP–Multiactor Decision Making

Alberto Turón and José María Moreno–Jiménez

Grupo Decisión Multicriterio Zaragoza
Facultad de Economía y Empresa. Universidad de Zaragoza
Zaragoza, Spain
Email: {turon, moreno}@unizar.es

***Abstract*—Collaborative decision making processes exchange information, data and opinions between the actors involved in their resolution. As a result, their preferences are often modified. In order to identify the social leaders (those who influence others), one must analyze the magnitude of the change in each actor's preference structure and its relation to the opinions and preferences expressed by the others. Networks created from the interactions between the actors permit to calculate measures of trust and reputation. In this work, we derive a measure of the influence received by the decision makers, obtained from their confidence in those with whom they interact during a decision making process, carried out by the Analytical Hierarchical Process (AHP) in the framework of e–Cognocracy.**

Keywords–AHP; e-Cognocracy; Trust; Reputation; Influence.

I. INTRODUCTION

Decision making in the Knowledge Society is a collaborative task; a correct decision requires individual motivations, but an effective decision also requires the acquisition of information from external sources to assess the outcomes of the decision made. In a decision making process, several actors or agents intervene, exchanging opinions and data, and providing arguments through debates.

These actors have channels through which to exchange this information, constituting a network in which this exchange often coexists with another series of actions or experiences shared by the same decision makers, belonging to areas beyond the decision in question. The set of actions that the actors carry out in the network, together with the information that some actors obtain from others, generate trust in one another. In turn, actors earn a reputation, which can make them influential. In order to understand the nature of the decision making processes, it is important to identify the social leaders -the persons whose opinions influence the preferences of others, and to obtain a measure of how they influence the other actors' preferences.

This paper details the way to obtain the network of influence of the actors involved in group decision and, from them, determine their influence, in the framework of a decision making process that uses the Analytic Hierarchy Process (AHP) under the paradigm of e-Cognocracy.

The rest of this paper is organized as follows. Section II introduces the concepts of reputation and influence, the methodology on which the calculation of influence, known as e-Cognocracy, is based, and the multicriteria approach used, AHP. Section III shows the proposed procedure for determining the influence of decision makers and their relationship with reputation. Section IV shows the results obtained in a real experience that was carried out following this methodology. Finally, Section V contains the most outstanding conclusions of this work, as well as possible extensions of the same and future lines of work.

II. BACKGROUND

The determination of influence requires the calculation of trust between actors and the reputation of each of them. On the other hand, the present study has been carried out using the AHP methodology for decision making, within the e-Cognocracy framework.

A. Trust, reputation and influence

Trust and reputation are studied in many different disciplines [1] as key factors to explain the behavior of people integrated into social networks.

We can consider that, given a set of actors $D = \{D_1, \ldots, D_N\}$, the trust τ_{ij} of the actor D_i in the actor D_j is the expectation that D_i puts in that D_j adopts a certain behavior at a given moment (see, for example, [2]). While the reputation r_i of the actor D_i is a measure of the prestige that D_i has among the other actors, understood as the perception that the agent creates past actions about its intentions and norms [1]. Trust is a subjective indicator, which is usually built on the basis of the personal impressions that an actor derives from another, through the observation of the interactions between them; the reputation of an actor is a single value obtained from observations carried out in the social network to which the actor belongs [3].

Finally, reputation of an actor can influence the preferences of other actors.

B. E–Cognocracy

The e-Cognocracy is a new model of democracy that emerged in 2003 as a system to integrate immigration into the Knowledge Society [4]. Since then, the Multicriteria Decision Making Group (GDMZ), a research group from the University of Zaragoza, has been developing new philosophical arguments to support its evolution and numerous technological and methodological tools for its implementation.

E-Cognocracy combines the two most widespread models of democracy at the beginning of the twenty-first century [5]: representative or liberal democracy and participatory or direct democracy. In this way, some of the limitations of representative democracies (lack of transparency and accountability of representatives, and lack of participation and control of citizens) and direct democracies (populism, overvaluation of

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individual interests, lack of a long-term vision of the system, etc.) are resolved.

In terms of its methodology, e-Cognocracy consists of seven basic stages: (i) problem formulation; (ii) first voting round; (iii) discussion; (iv) second voting round; (v) knowledge extraction, (vi) evaluation; (vii) documentation.

C. Analytic Hierarchy Process (AHP)

The AHP [6],[7] is a technique that allows the resolution of multicriteria, multienvironment and multiactor problems, incorporating into the model the subjective aspects and the inherent uncertainty in the decision making of real systems. This multicriteria technique combines the objective associated to traditional science with the subjective associated to human being. It also presents a well behavior in multiactor decision making. Some main features of this method are: the modeling of the problem through the construction of a hierarchy in which the relevant aspects of the problem (criteria, alternatives, etc.) are collected; the incorporation of preferences through pairwise comparisons; and the deduction of a ratio scale derived from relative preferences (judgements) measured on an absolute scale.

Another of the most outstanding features of this multicriterion methodology is the possibility of evaluating the decision maker's consistency in the issuance of judgments, not being necessary that such judgments be perfectly consistent or cardinal transitive.

Basically, the original AHP method consists of four stages: (1) construction of a model, in this case a hierarchy, that represents the decision problem; (2) incorporation of the decision maker's judgments; this is made by making paired comparisons between the elements of the same level of the hierarchy with respect to the common node of the next higher level; in this way, each judgment focuses on the comparison of two elements with respect to a single characteristic; (3) calculation, from the pairwise comparison matrices issued by the decision maker in the previous stage, of the values that determine the relative importance of the elements of a level with respect to a node of the higher level (local priorities) and then the global priorities of all the elements of the hierarchy are obtained; and (4) synthesis of the global priorities of the alternatives to obtain their total or final priorities.

III. Determination of the Influences

In a discrete multicriteria multiactor decision problem following the methodology of e-Cognocracy, the preference structure of each decision maker can be modified from the first round to the second. This modification may be due to the influence received during the discussion stage, after analyzing the contribution of the other actors. The result of all the interactions that take place during the debate process is a matrix of trusts $\mathcal{T} = (\tau_{ij})_{N\times N}$ (some may be empty, if there is no interaction between two actors), and a vector of reputations $R = (r_1, \ldots, r_N)^T$. The interactions between the decision makers (corresponding to the non-null elements of $\mathcal{T}$) define a network of trusts, that is, a directed acyclic graph $G(D, E)$ in which the vertices are the actors and $E = (e_{ij})$ is the matrix of adjacencies of the graph G:

$$e_{ij} = \begin{cases} 1 & \text{if } D_i \,\Re\, D_j \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

where $\Re$ is the relationship $D_i \,\Re\, D_j \Leftrightarrow D_j$ has generated trust in D_i.

If $A = \{A_1, \ldots, A_M\}$ are the alternatives and $w^k = (\omega_1^k, \ldots, \omega_M^k)$ the preference structure of the decision maker D_k, then $w^k \in \mathcal{S}^M$ for $k = 1, \ldots, N$, being

$$\mathcal{S}^M = \{(w_1, \ldots, w_M) \mid w_i \geq 0 \text{ and } \sum_{i=1}^{M} w_i = 1\} \quad (2)$$

the compositional space or *simplex* M-dimensional.

In order to determine the influence that each actor has received from those with whom it has interacted, the *center of influence* of each actor D_i is calculated, that is, a representative position of all the actors that have exerted their influence on him. This position corresponds to the arithmetic mean of the preference structures of the decision makers D_j belonging to his/her network of influences, weighted by the trust τ_{ij}:

$$\Pi_i = \left(\frac{\sum_{j=1}^{M} \tau_{ij} x_1^j e_{ij}}{\sum_{j=1}^{M} \tau_{ij} e_{ij}}, \ldots, \frac{\sum_{j=1}^{M} \tau_{ij} x_{M-1}^j e_{ij}}{\sum_{j=1}^{M} \tau_{ij} e_{ij}} \right) \quad (3)$$

and $x^j = (x_1^j, \ldots, x_{M-1}^j)$ is the projection of the preference structure w^j of actor D_j in the last round (final decision) on the Cartesian space $\mathbb{R}^{M-1}$, using the centered log-ratio transform

$$x_i^j = log \left(\frac{\omega_i^j}{\left(\prod_{k=1}^{M} \omega_k^j \right)^{1/M}} \right), i = 1, \ldots, M-1 \quad (4)$$

The purpose of this transformation is to convert a decision maker's preference structure into values for which it makes sense to calculate Cartesian distances. The extent to which the distance between the position of the decision maker D_i and his/her center of influence has changed between rounds is a measure of the influence received.

IV. Application to a Real Experience

In April 2015 an experiment was carried out on the selection of the best mobility strategy in the city of Zaragoza, taking as a starting point the tram line existing at that time. The problem consisted of four alternatives, proposed by four political parties, and was carried out in two voting rounds with an intermediate debate, in which the students of the subject *Electronic Government and Public Decisions* intervened, and to which were also invited the representatives of the political parties that presented candidacy to the Council of Zaragoza for the impending municipal elections [8]. In total, 27 people participated in the discussion, although only 16 of them participated in the two rounds of voting, and therefore they were the only ones with whom this study could be carried out. The discussion took place on the Social Cognocracy Network (SCN) [9], a social network designed by the GDMZ based on the e-Cognocracy. Through this social network, the discussion stage provides measures of the actors' trust and reputation [10].

After the first voting round, a discussion was developed in the forum, with the participation of the students and the political representatives. In the forum, each actor D_j could valuate the reputation of the others, as well as the importance of the topics and the comments to the topics that were posted, by giving values from 0 to 10 to three quantitative indices:

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Index	Rates
Trust τ_{ij}	The author D_i of a comment
T–importance I_{ij}^T	A topic T_i
C–importance I_{ij}^C	A comment C_i

Actors were also able to assess the importance of their own topics and comments, and even to rate themselves *(self-trust)*.

From these indices, the reputation r_i of each actor and the relevance of topics (R_i^T) and comments (R_i^C) were obtained, using the expressions:

$$r_i = \frac{\sum_{j=1}^{n} r_j \tau_{ij}}{\sum_{j=1}^{n} r_j}, R_i^T = \frac{\sum_{j=1}^{n} r_j I_{ij}^T}{\sum_{j=1}^{n} r_j}, \quad R_i^C = \left(1 + \frac{n_c}{N}\right) \frac{\sum_{j=1}^{n} r_j I_{ij}^C}{\sum_{j=1}^{n} r_j} \tag{5}$$

being N the total number of comments posted to a topic and n_c the number of answers to a specific comment in that topic. This process is recursive, so that a valuation emitted at an instant modifies the previous values, that are recalculated.

Then, a second voting round was performed, and the voters' preference structures were obtained.

Figure 1 shows the influence network obtained after the discussion stage, as well as the reputation and the preferred alternative of the actors who participated in the three stages. Table I shows the values obtained for the influence index after the two voting rounds and the discussion.

Analyzing the reputation and the influence indices, several well differentiated profiles are found:

1) Users with a high influence index and a low reputation, whose network of influence is formed by high reputation users: U00041G, U00057H.
2) Users with a low influence index and a high reputation, whose network of influence is formed by users of high reputation: U00002C, U00018D, L19, Omael for President, U00042C.
3) Users with a low influence index and a low reputation, whose network of influence is formed by high reputation users: U00003I, Johnny Snow, U00031B.
4) Other users: Humano anonimo, Paul Gascoigne, U00027C, U00034J, U00039J, U00047C.

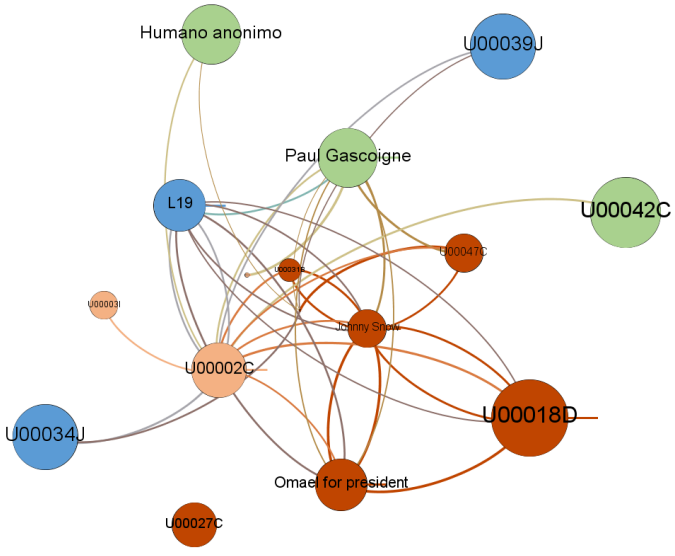

Figure 1. Network of influence created during the discussion in the forum. The colors represent the preferred alternative after the second voting round, and the size of each node is proportional to the reputation of the decision maker it represents.

Users with profile 4 correspond to cases in which no clear pattern can be identified, either because the number of influencers is scarce or because their network of influence is composed of people of very different reputations. The three other profiles are perfectly characterized, observing how all the decision makers with high influence index (first profile) have modified their main decision between one round and another, behavior that is not observed in the decision makers with low influence rates.

V. Conclusions and Future Work

Based on the reputations of the decision makers obtained in a multiactor decision making process, we construct an indicator of the influence that a decision maker receives from the actors with whom he interacts. This indicator makes it possible to identify the most influential actors and, consequently, those who have received a greater influence from others. These others can be identified through his/her network of influence.

Our future work will focus on the analysis of the content of the messages using text mining techniques, which will allow for the combination of the quantitative analysis with a qualitative analysis that accurately identifies the arguments presented during the debate.

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TABLE I. INFLUENCE INDICES.

Decision maker	*Reputation*	*Distance round 1*	*Distance round 2*	*Influence*	*Decision round 1*	*Decision round 2*
U00002C	6.19	0.66551	0.63466	-0.03085	A3	A2
U00003I	3.08	0.81759	1.13344	+0.31584	A2	A2
Johnny Snow	4.24	0.21064	0.16989	-0.04075	A4	A4
Humano anonimo	6.70	0.99191	0.89467	-0.09723	A3	A3
U00018D	8.75	0.41301	0.41553	+0.00253	A1	A4
L19	5.82	0.44337	0.68249	+0.23912	A1	A1
Paul Gascoigne	6.67	0.53453	0.00000	-0.53453	A3	A3
Omael for president	5.84	0.73748	0.67757	-0.05991	A3	A4
U00027C	5.00	1.26954	1.29257	+0.02303	A4	A4
U00031B	2.45	0.21124	0.06888	-0.14236	A4	A4
U00034J	7.38	1.54429	1.53257	-0.01172	A1	A1
U00039J	7.38	0.42917	0.76707	+0.33790	A4	A1
U00041G	0.31	0.40665	0.00000	-0.40665	A1	A2
U00042C	8.00	1.00044	0.71582	-0.28463	A2	A3
U00047C	4.23	0.49455	0.47847	-0.01608	A4	A4
U00057H	0.00	0.75448	1.54259	+0.78811	A3	A4

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