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A New Approach for Delphi Processes Based on Group Consensus with Linguistic Terms

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***Abstract*— A new approach for Delphi processes including a measure of consensus based on linguistic terms is introduced in this paper. The measure of consensus involves qualitative reasoning techniques and is based on the concept of entropy. In the proposed approach, consensus is reached automatically without the need for neither a moderator nor a final interaction among panelists. In addition, it permits panelists to answer with different levels of precision depending on their knowledge on each question. An illustrative example considering the opinions of stake holders in neonate health-care to reach a final consensual definition of chronic pain in neonates is presented.**

I. INTRODUCTION

Delphi technique [23] is a commonly used group decision-making method in which a panel of experts or stake holders anonymously tries to reach consensus on the significant features of a certain topic. It was introduced in the 1960s [10] and, since then, it has been used for achieving convergence of expert opinion within different areas of knowledge, such as program planning, needs assessment, policy determination, and resource utilization [17], [20], [33].

Delphi technique showed to have some practical advantages over other consensus-building methods, such as brainstorming, dialectical inquiry and nominal group [13], [20], [22], [23], [33]. Frequently, the group communication and consensus processes in these group decision-making methods are conducted by a moderator and involve several rounds. One of the main problems that share these methods is handling with uncertainty and linguistic terms in group assessments.

In the academic literature, several group decision-making methods have been developed to handle the uncertainty and linguistic information inherent to human consensus processes [5], [15], [1], [12], [13], [16]. These methods have nowadays a wide range of applications from managerial to medical or engineering areas [6], [9], [7], [28].

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A new approach of Delphi technique including linguistic variables has been developed in this paper. This new approach is based on a definition of a degree of consensus able to be used when participants' responses are given through linguistic terms. In addition, the methodology allows experts or participants to assess different statements with different levels of precision.

The rest of this paper is organized as follows: First the main features of Delphi processes are given in Section II. Section III introduces the theoretical framework for the new approach. Section IV presents the new approach for Delphi processes based on group consensus with linguistic terms. An illustrative example in the health-care sector is presented in Section V to show the performance of the new approach. Finally, Section V contains the main conclusions and lines of future research.

II. MAIN FEATURES OF DELPHI PROCESSES

The Delphi technique was developed in 1963 by Dalkey and Helmer and the Rand Corporation [10]. Usually this technique is used to: determine or define the set of possible alternatives, find implicit assumptions conducting to different judgements, explore new solutions for a specific problem, or reach consensus about a specific topic from a panel of experts or stake holders. Its design typically involves 3 to 4 rounds of questions. The first round uses open-ended questions to gather panelists' opinions. The results of this first round are categorized into items and in a second round these items or statements are valued by the panelists. In the consecutive rounds the values of the total panel are reported to the panelists who then are asked to re-assess their own values in the light of the group's opinion. In most cases, this type of iteration conducts to a consensus.

From our point of view, the main points of criticism on Delphi are the lack of a definition of a degree of consensus, the impossibility of handling the uncertainty involved in panelists' opinions, and the way in which some opinions are suppressed during the process.

To solve these problems, several fuzzy Delphi approaches have been developed and can be found in the literature. Initially, the application of fuzzy theory to the Delphi method by means of linguistic variables was introduced by Murray et al (1985) [25]. Kaufmann and Gupta (1988) introduced a fuzzy Delphi method considering optimistic, moderate and pessimistic assessments of experts via triangular fuzzy numbers [21]. Ishikawa et al. [19] used triangular fuzzy numbers to model expert judgments and reached consensus in only one round by the implementation of the max-min

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fuzzy Delphi method and a new Delphi method via fuzzy integration. Chang et al (2000) reviewed the previous fuzzy Delphi works and proposed a new fuzzy Delphi approach using fuzzy statistics [8]. In 2010, Hsu et al presented an application of fuzzy Delphi Method to obtain the critical factors of the regenerative technologies, using fuzzy AHP to find the importance degree of each factor [18]. Alonso et al (2010) proposed a web based consensus support system for group decision making problems and incomplete preferences, similar to Delphi method, but without relying on the use of questionnaires and where moderator tasks can be replaced [1]. Duru et al (2012) extended the recent literature via an implementation of fuzzy Delphi for the adjustment of statistical predictions. They proposed a fuzzy Delphi adjustment process for improvement of accuracy and introduced an empirical study to illustrate its performance [11].

This paper presents a new approach for Delphi processes based on a definition of a degree of consensus able to be used when experts responses (in round 2 and consecutive) are given through linguistic terms. Linguistic terms are handled by means of order-of-magnitude qualitative reasoning techniques. A detailed application of these techniques to group decision-making and consensual processes can be found in [29], [30].

III. Theoretical Framework

The use of linguistic terms based on order-of-magnitude qualitative reasoning techniques allows the adaptation of Delphi processes to the way humans express its unprecise and vague knowledge.

A. Linguistic Terms with Different Levels of Precision

The approach considers a finite set of *basic* qualitative labels, $\mathbb{S}_n^* = \{B_1, \dots, B_n\}$, which is totally ordered: $B_1 < \dots < B_n$. Usually, each basic qualitative label corresponds to a linguistic term, for instance for $n = 5$: B_1 = "Strongly disagree" $<$ B_2 = "Disagree" $<$ B_3 = "Neither agree nor disagree" $<$ B_4 = "Agree" $<$ B_5 = "Strongly agree".

The *complete universe of description* for the absolute order-of-magnitude space with granularity n, is the set $\mathbb{S}_n$:

$$\mathbb{S}_n = \mathbb{S}_n^* \cup \{[B_i, B_j] \,| B_i, B_j \in \mathbb{S}_n^*, i < j\},$$

where the *non-basic* label $[B_i, B_j]$ with $i < j$ is defined as the set $\{B_i, B_{i+1}, \dots, B_j\}$, whereas $[B_i, B_i] = B_i$.

Consistent with the former example of linguistic terms for $n = 5$, the non-basic label $[B_3, B_4]$ represents the linguistic term ["Neither agree nor disagree", "Agree"]. The linguistic term "Unknown" is represented by ["Strongly disagree", "Strongly agree"], i.e., $[B_1, B_5]$. This least precise qualitative label is denoted by the symbol ?, i.e., in $\mathbb{S}_n$, $[B_1, B_n] \equiv$?.

A normalized measure μ is taken into account in the set of basic qualitative labels, $\mu : \mathbb{S}_n^* \to [0, 1]$ such that $\sum_{B_i \in \mathbb{S}_n^*} \mu(B_i) = 1$. This measure can be directly extended to $\mathbb{S}_n$ by defining $\mu([B_i, B_j]) = \sum_{k=i}^{j} \mu(B_k)$.

The connex union and the intersection between qualitative labels are also considered in order to define the degree of consensus among a set of panelists' opinions [29]. Given two qualitative labels $[B_{i_1}, B_{j_1}], [B_{i_2}, B_{j_2}] \in \mathbb{S}_n$ their connex union is the qualitative label $[B_{i_1}, B_{j_1}] \sqcup [B_{i_2}, B_{j_2}] = [B_{\min(i_1,i_2)}, B_{\max(j_1,j_2)}]$. When $[B_{i_1}, B_{j_1}] \cap [B_{i_2}, B_{j_2}] \neq \emptyset$, their intersection is the qualitative label $[B_{i_1}, B_{j_1}] \cap [B_{i_2}, B_{j_2}] = [B_{\max(i_1,i_2)}, B_{\min(j_1,j_2)}]$.

When the intersection of a set of qualitative labels is empty, then an *iterative relaxation process* can be performed in order to reach a non-empty intersection among them (see a detailed explanation in [29]). The iterative relaxation process is done by means of a dive function ϕ which makes an immersion in a space with a greater granularity (with more levels of precision), $\phi : \mathbb{S}_n \to \mathbb{S}_{n+1}$, with $\phi([B_i, B_j]) = [B_i', B_{j+1}']$, as many times as necessary in order to get the desired non-empty intersection. When this process is conducted, the new measure μ' is computed applying as many times as necessary the next formulas:

$$\begin{aligned} \mu'(B_1') &= \frac{1}{2}\mu(B_1), \\ \mu'(B_i') &= \frac{1}{2}(\mu(B_{i-1}) + \mu(B_i)),\ i = 2, \dots, n \\ \mu'(B_{n+1}') &= \frac{1}{2}\mu(B_n) \end{aligned}$$

Then, a straightforward computation leads to the measure $\mu'([B_i', B_{j+1}'])$ for all $i, j = 1, \cdots, n$.

B. Degree of Consensus

Let us consider a panel of m stake holders and a set of statements Λ to be assessed from the second round on of the Delphi process. The new approach of Delphi processes proposed in this paper involves the notion of entropy of a qualitative label, defined in $\mathbb{S}_n$ from the Shannon entropy concept in information theory.

Definition 1: The entropy of a qualitative label $Q \in \mathbb{S}_n$ is defined as:

$$H(Q) = -\log_2(\mu(Q)),$$

where μ is the considered normalized measure in the set of basic qualitative labels.

The definition of the degree of consensus of the set of panelists with respect to a statement $a \in \Lambda$ is as follows:

Definition 2: Given m qualitative labels $Q_1, \cdots, Q_m \in \mathbb{S}_n$, associated to the assessments of m panelists for a given statement a, such that $\cap_{j=1}^m Q_j \neq \emptyset$, the *degree of consensus* with respect to a is:

$$\kappa(Q_1, \cdots, Q_m) = \frac{H(\sqcup_{j=1}^m Q_j)}{H(\cap_{j=1}^m Q_j))} = \frac{\log_2(\mu(\sqcup_{j=1}^m Q_j))}{\log_2(\mu(\cap_{j=1}^m Q_j))}$$

If the intersection of all the Q_j is empty, then the previously mentioned *iterative relaxation process* is performed in order to reach a non-empty intersection.

Note that in the case that panelists only use basic qualitative labels, the condition $\cap_{j=1}^m Q_j \neq \emptyset$ is only fulfilled when all the panelists' opinions are the same and then the degree of consensus is 1; otherwise, a lower degree of consensus is obtained.

Next example illustrates how the the diving function and the updating measure together with the proposed degree of consensus are computed.

Example 1: Let us consider the statement a = "Almost continuous pain longer than few hours" and a set of three panelists $\mathbb{E} = \{e_1, e_2, e_3\}$ consisting of a nurse e_1, a doctor e_2 and a mother e_3. Let us assume that the assessments of the three panelists with respect to a are represented by three qualitative labels defined as: $Q_1(a) = [B_1, B_2], Q_2(a) = B_3, Q_3(a) = B_2$ using the meaning of basic labels $B_1, \ldots, B_5$ given at the beginning of Subsection III.A. Finally, let us define $\mu(B_i) = 1/5, i = 1, \ldots, 5$.

Note that there is not consensus among the panelists' assessments because $Q_1(a) \cap Q_2(a) \cap Q_3(a) = [B_1, B_2] \cap B_3 \cap B_2 = \emptyset$. For this reason, the dive function must be applied once, obtaining a non-empty intersection: $\phi(Q_1(a)) \cap \phi(Q_2(a)) \cap \phi(Q_3(a)) = [B'_1, B'_3] \cap [B'_3, B'_4] \cap [B'_2, B'_3] = B'_3 \neq \emptyset$ and a new measure μ' in S^*_6 given by:

$$\mu'(B'_1) = \frac{1}{2}\mu(B_1) = \frac{1}{10};$$
$$\mu'(B'_i) = \frac{1}{2}(\mu(B_{i-1}) + \mu(B_i)) = \frac{1}{5}, i = 2, \ldots, 5;$$
$$\mu'(B'_6) = \frac{1}{2}\mu(B_n) = \frac{1}{10}.$$

Then, since $\sqcup_{k=1}^{3}\phi(Q_i(a)) = [B'_1, B'_3] \sqcup [B'_3, B'_4] \sqcup [B'_2, B'_3] = [B'_1, B'_4]$ and $\cap_{k=1}^{3}\phi(Q_i(a)) = [B'_1, B'_3] \cap [B'_3, B'_4] \cap [B'_2, B'_3] = B'_3$ the degree of consensus is:

$$\kappa(Q_1, Q_2, Q_3) = \frac{H(\sqcup_{k=1}^{3}\phi(Q_i(a)))}{H(\cap_{k=1}^{3}\phi(Q_i(a))))} = \frac{H([B'_1, B'_4])}{H(B'_3)} =$$

$$= \frac{\log_2 7/10}{\log_2 1/5} = 0.22$$

This value of $\kappa(Q_1, Q_2, Q_3)$ suggests a low level of consensus among panelists, consistent with intuition. Next example presents results when different initial panelists' assessments are considered.

Example 2: Case A. Analogously to Example 1, let us assume now that the assessments of the three panelists with respect to a are represented by: $Q_1(a) = [B_1, B_2], Q_2(a) = [B_1, B_2], Q_3(a) = B_2$ using the same meaning of basic labels $B_1, \ldots, B_5$ given at the beginning of Subsection III.A. and the same measure μ as in the above example.

In this case there is consensus among the panelists' assessments because $Q_1(a) \cap Q_2(a) \cap Q_3(a) = B_2$. Then, since $\sqcup_{k=1}^{3}(Q_i(a)) = [B_1, B_2]$ and $\cap_{k=1}^{3}(Q_i(a)) = B_2$ the degree of consensus is:

$$\kappa(Q_1, Q_2, Q_3) = \frac{H(\sqcup_{k=1}^{3}(Q_i(a)))}{H(\cap_{k=1}^{3}(Q_i(a))))} = \frac{H([B_1, B_2])}{H(B_2)} =$$

$$= \frac{\log_2 2/5}{\log_2 1/5} = 0.57$$

Case B. Finally, let us consider the extreme case in which two panelists's opinions are "strongly disagree" and "strongly agree", i.e., the assessments of the three panelists with respect to a are represented by: $Q_1(a) = B_1, Q_2(a) = B_1, Q_3(a) = B_5$ using the same meaning of basic labels and the same measure as above. Obviously, there is not consensus among the panelists' assessments and the dive function must be applied four times in order to obtain a non-empty intersection: $(\phi_4 \circ \phi_3 \circ \phi_2 \circ \phi_1)(Q_1(a)) \cap (\phi_4 \circ \phi_3 \circ \phi_2 \circ \phi_1)(Q_2(a)) \cap (\phi_4 \circ \phi_3 \circ \phi_2 \circ \phi_1)(Q_3(a)) = [B''''_1, B''''_5] \cap [B''''_1, B''''_5] \cap [B''''_5, B''''_9] = B''''_5$. Then, since $\sqcup_{k=1}^{3}\phi^{(4)}(Q_i(a)) = [B''''_1, B''''_9] = ?$ and $\cap_{k=1}^{3}\phi^{(4)}(Q_i(a)) = B''''_5$, computing the their values through the updating measure μ'''' the degree of consensus is:

$$\kappa(Q_1, Q_2, Q_3) = \frac{H([B''''_1, B''''_9])}{H(B''''_5)} =$$

$$= \frac{\log_2 1}{\log_2 16/80} = 0$$

Finally, Table I presents a comparison of the results obtained using the degree of consensus proposed in this paper in Examples 1 and 2 together with the classical statistical parameters that would be used in classical Delphi.

TABLE I
RESULTS EXAMPLES 1 AND 2

	Panelists assessments			Common (Value of consensus)	Degree of consensus κ	Mean μ	Standard deviation *SD*
	Q_1	Q_2	Q_3				
Ex 1	$[B_1,B_2]$	B_3	B_2	B'_3	0.22	2.17	0.62
Ex2A	$[B_1,B_2]$	$[B_1,B_2]$	B_2	B_2	0.57	1.67	0.24
Ex2B	B_1	B_1	B_5	B''''_5	0	2.33	1.89

Comparing the outputs produced by the proposed degree of consensus with the classical statistical parameters, it can be seen that the new measurement is more consistent with human intuition on consensus. Note that the proposed methodology allows us to compute a measure of consensus even in the cases where the panelists's opinions have initially no intersection. It takes into account the necessary effort that would be needed to reach consensus. However, in the extreme case in which two panelists's opinions are "strongly disagree" and "strongly agree", the degree of consensus is 0.

IV. A NEW APPROACH FOR DELPHI PROCESSES

The new approach for Delphi processes is based on the degree of consensus introduced in Subsection III.B to rank the statements in view of the assessments given by a panel of stake holders through a Delphi survey. Assessments are expressed using a set of linguistic terms with different levels of precision, and the new approach has the ability to reach consensus automatically without the need for neither a moderator nor an interaction between participants (see Subsection III.A). In addition, the proposed approach enables the handling of imprecise information given by evaluators without prior normalization.

Specifically, in the new approach, the theoretical framework introduced in the previous section is applied in three steps: First, in the interaction with panelists in rounds 2 and 3, as they can assess statements using different levels of precision. Second, in the computation of the degree of consensus. Third, in the selection of statements. In this way, the proposed consensus scheme allows us to detect statements for which most participants are in consensus (see Figure 1).

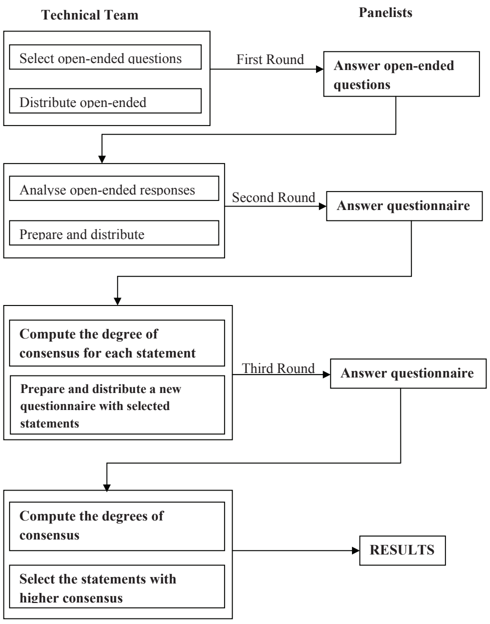

Fig. 1. The new scheme of the Delphi process

Figure 1 shows an scheme for the new approach for Delphi processes, where the differences with classical Delphi are highlighted in bold.

V. An Illustrative Example in the Health-care Sector

This section focusses on the definition of chronic pain in neonates by selecting its specific diagnostic determinants from a perspective of consensus in group decision-making. An analysis of the opinions given by doctors, nurses and other stake holders is conducted by implementing the proposed new approach for Delphi processes.

A web-based, three round Delphi survey was performed to provide a definition, the etiology and the specific diagnostic determinants of chronic pain in the newborn. The survey, considering the three mentioned aspects, was carried out by the Department of Neonatology of the Máxima Medical Center in The Netherlands. An international panel of experts (health-care providers and parents) in the field of neonatology and neonatal pain was invited to participate. In this section, the introduced methodology is applied to find a consensus among panelists with respect to the definition of chronic pain in the newborn considering the panelists' responses in the last round of the Delphi process. This real case example shows the potential and benefits of the presented methodology.

A. Data description

Participants ($n = 189$) answered in the first round the open-ended questions *define chronic pain in own words*. The answers were categorized and summarized into 114 statements, which were valued by the participants ($n = 189$) on a 5-point Likert scale. In the second round the remaining participants ($n = 72$) were asked to reflect on a selection of 25 statements with a mode or median ≥ 4 or mean ≥ 3.75. These threshold values were used to provide the opportunity to easily reach consensus in the following round. In the third and last round the remaining participants ($n = 33$) were provided with the group response and their individual response.

B. Experimental results

Considering the results given by participants in the third round about the obtained 25 statements, a comparison between the results of the classical Delphi methodology and the methodology presented in this paper has been carried out.

In this case, the classical Delphi methodology selects those statements with mode, mean and median ≥ 4 simultaneously, resulting in 12 statements. On the other hand, the methodology presented in this paper has been applied to select the most consensual statements among the obtained 25 statements. The iterative relaxation process explained in Section III was applied resulting in 7 statements, in which the participants reached a degree of consensus over 0.20 (see Table II).

Note that, in Table II, numbers in bold correspond to those statements selected either by the classical method or the new approach. In addition, shaded rows indicate the 5 statements selected by both methods.

TABLE II

Obtained results

	Classical Delphi				New approach
Statements	Mode	Median	Mean	SD	Degree of Consensus
Chronic pain in the newborn may lead to a state where any interaction/procedure that is happening to the infant is perceived as painful.	**4**	**4**	**4,22**	0,55	**0,37**
Chronic pain may likely prolong hospitalization, worsening or adding to the existing morbidities.	**4**	**4**	**4,17**	0,65	**0,37**
Both recurrent and long lasting pain may become chronic.	**4**	**4**	**4,13**	0,78	0,09
Pain that occurs over a period of time, which is ongoing and has no obvious end point in site.	**4**	**4**	**4,13**	0,98	0,09
Chronic pain depletes stress hormones and increases energy consumption therefore interfering with growth.	**4**	**4**	**4,1**	0,92	0,09
Treatment should be based on signs of relief or comfort.	**4**	**4**	**4,1**	0,61	**0,37**
It can be anywhere in the body depending on the reason for the pain.	**4**	**4**	**4,07**	0,74	0,09
This pain often cannot be associated with a specific etiology but might well be from a combination of things.	**4**	**4**	**4,07**	0,37	**0,98**
Pain that is ongoing, no longer proximate to a procedure or event.	**4**	**4**	**4.03**	0,69	0,09
A painful event may also alter perception causing events that normally would be tolerate to be perceived as painful, leading to a chronic (longer duration) pain response.	**4**	**4**	**4.03**	0,72	**0,37**
Poorly controlled acute pain may lead to hyperalgesia, altered pain perception, and possibly a predilection to chronic pain states.	**4**	**4**	**4,01**	0,85	0,09
Daily continuous or intermittent episodes of painful sensations in the newborn.	**4**	**4**	**4**	0,69	0,09
Pain lasting more than 1 week that does not fall under the category of acute pain.	4	3	3,79	0,90	**0,24**
Pain lasting hours or days.	4	3	3,99	0.94	**0,24**

Table III shows the coincidences and divergences between results of both methods over all the 25 statements. In 68%

of the statements, the new mathematical approach agreed with classical Delphi: 20% of the statements were selected by both methods, whereas 48% were not. Two statements not selected by classical Delphi would have been considered using the new method. These two statements suggest to incorporate a time variable in the definition of chronic pain. Using classical Delphi method, no time variable was selected. On the other hand, seven statements among those selected by classical Delphi would not have been considered with the new approach. These seven statements express more than one concept each, this could be quite confusing for the panelists, and this confusion is captured by the proposed methodology. In the group of statements that were selected by both methods, in general, those with high mean values and post hoc calculated small standard deviation show a high level of agreement (degree of consensus) using the new method.

TABLE III
COMPARISON TABLE

	Selected by first method	Not selected by first method
Selected by second method	20%	8%
Not selected by second method	24%	48%

A limitation of this illustrative example is that stake holders were forced to value statements using a 5-point Likert scale predefined values, while they might want to rate using less precise values. For this reason, although the proposed methodology would have been able to deal with that imprecision, it has been applied assuming that all the assessments were given by basic labels.

VI. CONCLUSIONS

This paper puts forward a method, based on consensus measurement, for synthesizing the opinions given by a panel of stake holders through a Delphi survey. Evaluations are expressed using a set of linguistic labels describing order-of-magnitude. The method is based on the concept of entropy and has the ability to reach consensus automatically without the need for neither a moderator nor an interaction between participants. The method enables the handling of imprecise information given by evaluators without prior normalization.

The approach has three main advantages. First, it takes into account the different degrees of strictness of the evaluators' opinions. Second, it removes the need to calculate an average value of ordinal data. Third, the method accommodates "unknown values" by using the label "?" defined in the absolute order-of-magnitude qualitative model.

The proposed approach has been applied to define chronic pain in neonates and a comparison with a statistical study of the stake holders' opinions has been carried out. There is 60% congruence between the new method and traditional statistics.

Three main lines of future research are currently under consideration. First, from a theoretical point of view, the introduction of machine learning techniques will be explored, which will allow the updating of information and landmarks for selection of statements in each round. Second, a web-based software tool capable of gathering and summarizing opinions and working simultaneously with different levels of precision is being developed for Delphi processes using the concepts presented in this paper. Finally, regarding the real case study, the nature of the 40% difference between the methods should be explored and cut-off points should be validated. The theory presented in this paper has the potential for application in a broad field or domain, including consumer ratings and evaluation or accreditation processes.

REFERENCES

[1] Alonso, S., Herrera-Viedma, E., Chiclana, F., Herrera, F. 2010. A web based consensus support system for group decision making problems and incomplete preferences. *Information Sciences*, 180 (23), 4477-4495.

[2] American Academy of Pediatrics, Committee on Fetus and Newborn and Section on Surgery, Section on Anesthesiology and Pain Medicine, and Canadian Paediatric Society and Fetus and Newborn Committee. Prevention and Management of Pain in the Neonate: An Update. *Pediatrics,*118 (5), 2231-2241. 2006.

[3] Anand, K. J., Scalzo,F.M. Can Adverse Neonatal Experiences Alter Brain Development and Subsequent Behavior? *BIOLOGY OF THE NEONATE,* 77 (2),69-82. 2000.

[4] Anand, K. J., Stevens, B. J., McGrath, P. *Pain in Neonates and Infants*. Pain Research and Clinical Management Series. Elsevier. 2007.

[5] Beddoe, G.R., Petrovic, S. . Selecting and weighting features using a genetic algorithm in a case-based reasoning approach to personnel rostering. *European Journal of Operational Research*, 175 (2), 649-671. 2006.

[6] Belacel, N. 2000. Multicriteria assignment method PROAFTN: Methodology and medical application. *European Journal of Operational Research*, 125, 175-183.

[7] Canha, L., Ekel, P., Queiroz, J., Schuffner Neto, F. 2007. Models and methods of decision making in fuzzy environment and their applications to power engineering problems. *Numerical Linear Algebra with Applications*, 14, 369-390.

[8] Chang, P. T., Huang, L. C., Lin, H. J., 2000. The fuzzy Delphi method via fuzzy statistics and membership function fitting and an application to the human resources. *Fuzzy Sets and Systems*, 112, 511-520.

[9] Choudhury, A.K., Shankar, R., Tiwari, M.K. 2006. Consensus-based intelligent group decision-making model for the selection of advanced technology. *Decision Support Systems*, 42 (3), 1776-1799.

[10] Dalkey, N. C. and Helmer, O. 1963. An experimental application of the Delphi method to the use of experts. *Management Science*, 9 (3), 458-467.

[11] Duru, O., Bulut, E., Yoshida, S., 2012. A fuzzy extended DELPHI method for adjustment of statistical time series prediction: An empirical study on dry bulk freight market case. *Expert Systems with Applications* 39, 840-848.

[12] Eklund, P., Rusinowska, A., De Swart, H. 2007. Consensus Reaching in committees. *European Journal of Operational Research*, 178, 185-193.

[13] Fu, C., Yang, S-L. 2011. An attribute weight based feedback model for multiple attributive group decision analysis problems with group consensus requirements in evidential reasoning context. *European Journal of Operational Research*, 212, 179-189

[14] Ganzewinkel, C.J. van, Andriessen, P. Chronic pain in the neonate: A research design connecting ancient delphi to the modern 'dutch polder' *Journal of Research in Nursing.* Published ahead of print, february 8th. 2011.

[15] Herrera, F., López, E., Mendaña, C., Rodríguez, M. A. Solving an assignment-selection problem with verbal information and using genetic algorithms. *European Journal of Operational Research* 119 (2), 326-337. 1999.

[16] Herrera-Viedma, E., Herrera, F., Chiclana, F. 2002. A consensus model for multiperson decision making with different preference structures. *IEEE Transactions on Systems, Man and Cybernetics, Part A: Systems and Humans* 32, 394-402.

[17] Holsapple, C.W., Joshi, K.D., 2002. Knowledge manipulation activities: results of a Delphi study. *Information & Management* 39, 477-490.

[18] Hsu, Y-L, Lee, C-H, Kreng, V.B., 2010. The application of Fuzzy Delphi Method and Fuzzy AHP in lubricant regenerative technology selection. *Expert Systems with Applications* 37, 419-425.

[19] Ishikawa, A., Amagasa, M., Shiga, T., Tomizawa, G., Tatsuta, R., & Mieno, H., 1993. The max-min Delphi method and fuzzy Delphi method via fuzzy integration. *Fuzzy Sets and Systems*, 55, 241-253.

[20] Juan, Y.K., Castro, D., Roper, K., 2010. Decision support approach based on multiple objectives and resources for assessing the relocation plan of dangerous hillside aggregations *European Journal of Operational Research* 202 (1), 265-272,

[21] Kaufmann, A., Gupta, M.M., 1988. *Fuzzy Mathematical Models in Engineering and Management Science*, North-Holland, Amsterdam.

[22] Keeney S., Hasson, F., McKenna, H.P., 2001. A critical review of the delphi technique as a research methodology for nursing *Int J Nurs Stud.* 38, 195-200.

[23] Linstone, H.A., Turoff, M. 1979. *The Delphi Method: Techniques and Applications*, Addison-Wesley, London, 1979.

[24] McClain, B. C. and Kain, Z. N. 2005. Procedural Pain in Neonates: The New Millennium. *Pediatrics,*115 (4), 1073-1075.

[25] Murray, T. J., Pipino, L. L. and Gigch, J. P., 1985, A Pilot Study of Fuzzy Set Modification of Delphi, *Human Systems Management*, 5, 76-80.

[26] Page, GG. Are there long-term consequences of pain in newborn or very young infants? *The Journal of Perinatal Education.* 2004;13(3):10-17.

[27] Polit, D.F., Beck, C.T. 2007. *Nursing research, principles and method* (7th ed). Lippincott Williams & Wilkins, Philadelphia.

[28] Porcel, C., Herrera-Viedma, E. 2010. Dealing with incomplete information in a fuzzy linguistic recommender system to disseminate information in university digital libraries. *Knowledge Based Systems*, 23, 32-39.

[29] Roselló, L., Prats, F., Agell, N., Sánchez, M. 2010. Measuring consensus in group decisions by means of qualitative reasoning. *International Journal of Approximate Reasoning* 51, 441-452,

[30] Roselló, L., Prats, F., Agell, N., Sánchez, M. 2011. A qualitative reasoning approach to measure consensus. En: E. Herrera-Viedma *et al.* (Eds.), *Consensual Processes*, STUDFUZZ, vol. 267, Springer, Heidelberg, 235-261.

[31] Roselló,L., Sánchez, M., Agell, N., Prats, F., Mazaira, F.A. 2014. Using consensus and distances between generalized multi-attribute linguistic assessments for group decision-making. *Information Fusion*, 17, 83-92.

[32] Travé-Massuyès, L., Dague, P. (Eds.), 2003 *Modèles et Raisonnements Qualitatifs*. Hermes Science, París.

[33] Wu, C-R, Lin, C-T, Tsai, P-H. 2010. Evaluating business performance of wealth management banks *European Journal of Operational Research,* 207 (2), 971-979.