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Comprehensive Minimum Cost Consensus Models for ELICIT Information

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***Abstract*—Minimum cost consensus (MCC) models aim at obtaining a consensual solution that minimizes the cost of changing experts' preferences in the resolution of a Group Decision-Making (GDM) problem by assuring that the distance between each expert's individual opinion and the collective one is lower than a certain threshold. In order to improve these models, Comprehensive MCC (CMCC) models were developed to include a consensus measure in the optimization model. These proposals were initially defined to deal with numerical assessments and the use of linguistic information was neglected because discrete changes across the linguistic scale imply either lost of information, deadlocks, or lack of interpretable results. In order to overcome these limitations, the Extended Comparative Linguistic Expressions with Symbolic Translation (ELICIT) framework was proposed to provide a flexible continuous linguistic representation and precise linguistic computations without any loss of understandability or information. Therefore, this contribution aims at using the properties of the ELICIT information to define CMCC models for linguistic information which inherit the advantages of numeric CMCC in a Computing with Words environment.**

***Index Terms*—Minimum cost consensus metric, ELICIT information, Computing with Words**

I. Introduction

Nowadays, technological advances have led to data-driven models that automatically deal with decision-making processes [1], [2]. Nevertheless, many real-world decision problems require the participation of experts in a certain area to address those situations in which the available data are either vague or imprecise, giving rise to GDM problems [3], [4]. In Linguistic Decision-Making (LiDM), this uncertainty is usually modeled using linguistic information due to its closeness to the common human-being language [5]. Once the linguistic preferences are elicited from the corresponding decision-makers (DMs), Computing with Words (CW) methods are used to manipulate these original values and obtain linguistic results. However, the use of linguistic information may imply a loss of information during the decision processes and, consequently, unreliable results [6].

To overcome this drawback, Extended Comparative Linguistic Expressions with Symbolic Translation (ELICIT) information [7] was proposed as a CW framework that can model in a flexible way the linguistic preferences and their uncertainty and hesitancy using linguistic expressions, but without losing information or understandability. Despite ELICIT information presents several advantages regarding decision methods, researchers have not yet exploited its potential in consensus approaches for LiDM due to its short age.

Consensus models [8]–[11] emerge to deal with group decision situations in which experts involved in the decision problem must come to an agreement. Among other proposals to model these consensus processes [12], MCC models [13] were defined as mathematical programming problems in which a cost function, which measures the price of changing the original preferences of the involved experts, is minimized by guaranteeing a certain similarity between the individual opinions and the group collective opinion. However, such a similarity between experts and collective opinion does not necessarily guarantee the achievement of a certain level of consensus. For this reason, CMCC models [14] were defined as an improvement of the former proposal which also consider a consensus measure in the optimization problem. Despite this upgrade, the CMCC was initially introduced to deal exclusively with numerical assessments, whereas linguistic information was neglected.

Therefore, this proposal aims to introduce an optimal cost-based GDM consensus model for ELICIT information. Concretely, here it is proposed a CW-based CMCC model whose input and output values are ELICIT assessments, and, in addition, it is guaranteed that such linguistic modified preferences are close enough to the group collective opinion and also that the corresponding consensus measure reaches a certain consensus level.

To summarize, the main merits of the ELICIT-CMCC model are:

- It is an MCC model designed for linguistic information that obtains interpretable linguistic results (CW).
- The use of ELICIT information allows modeling DMs' hesitancy using flexible linguistic expressions and making precise computations with them.
- The corresponding automatic CRP guarantees that the obtained modified preferences are the closest to DMs' original opinions by ensuring both a maximum distance to the collective opinion and a certain consensus degree.

The remainder of this contribution is as follows. Section II summarizes some basic notions about GDM, consensus models, ELICIT information and CMCC models. In Section

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III a CW approach for CMCC models based on ELICIT information is introduced. Section IV shows the use of the proposed ELICIT-CMCC models in an illustrative problem, and Section V provides the corresponding comparative analysis. Finally, Section VI concludes the contribution.

II. Preliminaries

This section reviews the basic concepts required to easily understand this proposal.

A. Group Decision-Making and Consensus Reaching Processes

Some complex decision situations in which the available information is not based on objective values, but on subjective qualitative assessments generally require the participation of multiple DMs to have a multiperspective view of the decision problem. These types of problem are known in the specialized literature as GDM problems.

Formally, a GDM problem is a decision situation in which a group of $m \in \mathbb{N}$ DMs $E = \{e_1, e_2, ..., e_m\}$ must find a collective solution from a set of $n \in N$ alternatives $X = \{X_1, X_2, ..., X_n\}$. To do so, the DMs $e_k,\ k \in \{1, 2, ..., m\}$, express their opinion using a certain preference structure [8], [15].

In GDM problems, it is common to face real-world scenarios in which some DMs may reject the alternative chosen by the group because these stakeholders could feel that their opinions have not been considered. To soften such conflicts, Consensus Reaching Processes (CRPs) are applied to reach agreed solutions [14], [16]. A CRP is an iterative discussion process that uses a consensus measure to compute the closeness among DMs' preferences and finishes when either a consensus level ($\mu \in [0, 1]$) or a maximum number of allowed rounds is achieved. Such consensus measures are usually classified into two categories [17]:

- Distance-to-collective-based consensus measure.
- Distance-between-DMs-based consensus measure.

B. Linguistic Group Decision Making

Due to the lack of information, hesitancy about the correct answer or subjectivity, real-world decision-making problems are often defined under uncertainty contexts, especially when human DMs are involved.

To model such an uncertainty in a satisfactory way, during the last decades researchers have focused their investigation on linguistic GDM, in which the DMs' preferences are elicited using linguistic information. Particularly, one of the most widely-extended methodologies is the fuzzy linguistic approach [18], which relies on fuzzy set theory.

Fuzzy sets are a generalized version of classical sets, in which the membership function may take any value in the interval $[0, 1]$, whereas the characteristic functions of classical sets can just take the values 0 or 1. In other words, if X is the universe of discourse a fuzzy set is unequivocally defined by its membership function $\tilde{A} : X \to [0, 1]$, which assigns a membership degree $\tilde{A}(x) \in [0, 1]$ to every element in X.

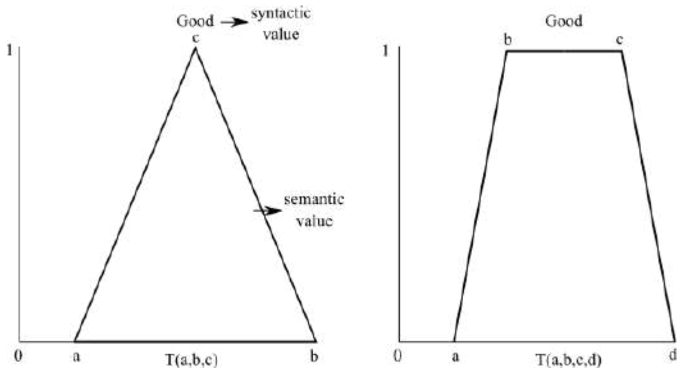

Fig. 1. Linguistic label

The fuzzy linguistic approach consists of modeling uncertainty using linguistic variables [18], which are characterized by a quintuple $(H, T(H), U, G, M)$ in which H is the name of the variable, $T(H)$ is the set of names of linguistic values of H, U is the universe of discourse, G is a syntactic rule for generating the names of values of H and M is a semantics rule for associating its meaning with each H, that is, $M(X)$ is a fuzzy subset of U [19] defined by a membership function with different graphic representations such as triangular or trapezoidal (see Fig. 1).

The use of linguistic information in GDM implies computing with words. Different proposals have been introduced to model and compute with linguistic information [20] such as 2-tuple linguistic values [6], Comparative Linguistic Expressions (CLEs) [21] or ELICIT information [7]. Such proposals have aimed at improving the accuracy and interpretability of the computing with words results.

C. 2-tuple linguistic model

Classical linguistic computational models presented drawbacks related to either the interpretability or the precision of the results. To overcome these limitations, the 2-tuple linguistic model [6] was introduced as a CW representation linguistic model, which allows precise computations with linguistic labels.

A 2-tuple linguistic value is a tuple $(s_i, \alpha) \in \overline{S} := S \times [-0.5, 0.5[$, where s_i is a linguistic term that belongs to a certain linguistic term set $S = \{s_0, s_1, \dots s_g\}$ (for a fixed even number $g \in \mathbb{N}$) and α is the so-called symbolic translation, i.e., a numerical value that represents the shifting of s_i fuzzy membership function (see Fig. 2). Note that for a 2-tuple expression $(s_i, \alpha) \in \overline{S}$, the possible values for its symbolic translation α are:

$$\alpha \in \begin{cases} [-0.5, 0.5) & if\ s_i \in \{s_1, s_2, \dots, s_{g-1}\} \\ [0, 0.5) & if\ s_i = s_0 \\ [-0.5, 0] & if\ s_i = s_g \end{cases}$$

The essential feature of the 2-tuple linguistic expressions is the fact that they can be translated into a numerical quantity $x \in [0, g]$, which simplifies the calculations:

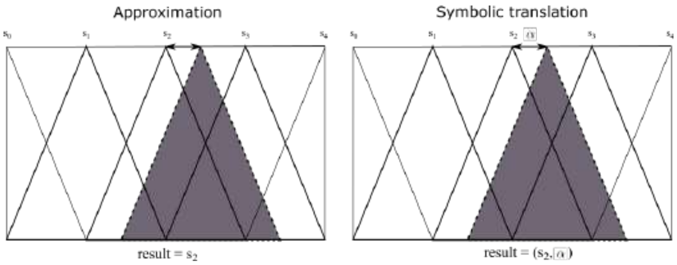

Fig. 2. Symbolic translation

Proposition 1. *[6] Let $S = \{s_0, \ldots s_g\}$ be a linguistic term set. Then, the function $\Delta^{-1} : \overline{S} \rightarrow [0, g]$ defined by*

$$\Delta_S^{-1}(s_i, \alpha) = i + \alpha, \ \forall \ (s_i, \alpha) \in \overline{S}$$

is a bijection whose inverse $\Delta_S : [0, g] \rightarrow \overline{S}$ is given by

$$\Delta_S(x) = (s_{round(x)}, x - round(x)) \ \forall \ x \in [0, g],$$

where $round(\cdot)$ is the function that assigns the closest integer number $i \in \{0, \ldots, g\}$.

D. Extended Comparative Linguistic Expressions with Symbolic Translation

In spite of the fact that the 2-tuple linguistic representation allows performing accurate computations by means of linguistic terms, it has an important limitation related to the lack of expressiveness, since these values cannot model the DMs' hesitancy between several linguistic terms such as Hesitant Fuzzy Linguistic Term sets (HFLTS) [22] do. Labella et al. [7] introduced ELICIT information to overcome this drawback by preserving the precision and understandability of the 2-tuple linguistic representation and improving the expressiveness by hybridizing it with HFLTS.

ELICIT values are generated by a context-free grammar that models comparative linguistic structures close to the language used by human beings such as *at least bad*, *at most fast* or *between expensive and rather expensive*. In addition, ELICIT information uses the symbolic translation concept from the 2-tuple linguistic model (see Section II-C) to perform computations without approximations to the real results and avoid loss of information.

Definition 1. *[7] Let G_H be a context-free grammar and $S = \{s_0, \ldots, s_g\}$ a linguistic term set. The elements of $G_H = (V_N, V_T, I, P)$ are defined as follows:*

$V_N = \{\langle continuous\ primary\ term \rangle, \langle composite\ term \rangle,$
$\langle unary\ relation \rangle, \langle binary\ relation \rangle, \langle conjunction \rangle\}$
$V_T = \{at\ least,\ at\ most,\ between,\ and,\ (s_0, \alpha)^\gamma,$
$(s_1, \alpha)^\gamma, \ldots, (s_g, \alpha)^\gamma\}$
$I \in V_N$
$P = \{I\ ::=\ \langle continuous\ primary\ term \rangle |$
$\langle composite\ term \rangle$
$\langle composite\ term \rangle\ ::=\ \langle unary\ relation \rangle$
$\langle continuous\ primary\ term \rangle |$
$\langle binary\ relation \rangle \langle continuous\ primary\ term \rangle$
$\langle conjunction \rangle \langle continuous\ primary\ term \rangle$
$\langle continuous\ primary\ term \rangle\ ::=\ (s_0, \alpha)^\gamma |$
$(s_1, \alpha)^\gamma | \ldots | (s_g, \alpha)^\gamma$
$\langle unary\ relation \rangle\ ::=\ at\ least | at\ most$
$\langle binary\ relation \rangle\ ::=\ between$
$\langle conjunction \rangle\ ::=\ and\}$

Thus, this context-free grammar together with a linguistic term set, for instance,

$$S = \{\text{Much Worse(MW)}, \text{Worse(W)}, \text{Slightly Worse(SW)} \\ \text{Equal(E)}, \text{Slightly Better(SB)}, \text{Better(B)}, \text{Much Better(MB)}\}.$$

can model linguistic expressions such as, *at least* $(MW, 0.2)^{0.1}$, *at most* $(W, -0.1)^{0.12}$ or *between* $(E, 0)^{-0.11}$ *and* $(SB, 0.32)^0$. Notice the γ parameter is used to perform fuzzy computations with ELICIT information [7]. To do so, the ELICIT values are transformed into trapezoidal fuzzy numbers (TrFNs) by means of the fuzzy envelope computation [7]:

Definition 2. *[7] Let $[\overline{s}_1, \overline{s}_m]_{\gamma_1, \gamma_2}$, where $[\overline{s}_1, \overline{s}_m] := \{\overline{s}_1, \overline{s}_2, ..., \overline{s}_m\} \subset \overline{S}$ is a set of ordered 2-tuple linguistic values, be an ELICIT expression. The fuzzy envelope of $[\overline{s}_1, \overline{s}_m]_{\gamma_1, \gamma_2}$, $env([\overline{s}_1, \overline{s}_m]_{\gamma_1, \gamma_2})$, is defined as the TrFN $T(a, b, c, d)$ where:*

$$a = \gamma_1 + \max\left\{\frac{\Delta_S^{-1}(\overline{s}_1) - \frac{1}{g}}{g}, 0\right\}, b = \frac{\Delta_S^{-1}(\overline{s}_1)}{g},$$
$$c = \frac{\Delta_S^{-1}(\overline{s}_m)}{g}, d = \gamma_2 + \min\left\{\frac{\Delta_S^{-1}(\overline{s}_m) + \frac{1}{g}}{g}, 1\right\}.$$

Furthermore, the ELICIT computational model follows a CW approach that computes on the fuzzy envelopes of the respective linguistic expressions, whose results are then retranslated into ELICIT information. In other words, any TrFN can be unequivocally represented as an ELICIT value. For the sake of clarity, the set of all TrFNs on the interval $[0, 1]$ will be denoted by

$$\mathcal{T} = \{T : [0, 1] \rightarrow [0, 1] \ : \ T \text{ is a TrFN}\}$$

Proposition 2. *Let $\overline{\overline{S}}$ be the set of all possible ELICIT values. Then the mapping $\zeta^{-1} : \overline{\overline{S}} \rightarrow \mathcal{T}$*

$$\zeta^{-1} : \overline{\overline{S}} \rightarrow \mathcal{T}$$
$$[\overline{s}_1, \overline{s}_2]_{\gamma_1, \gamma_2} \rightarrow T(a, b, c, d)$$

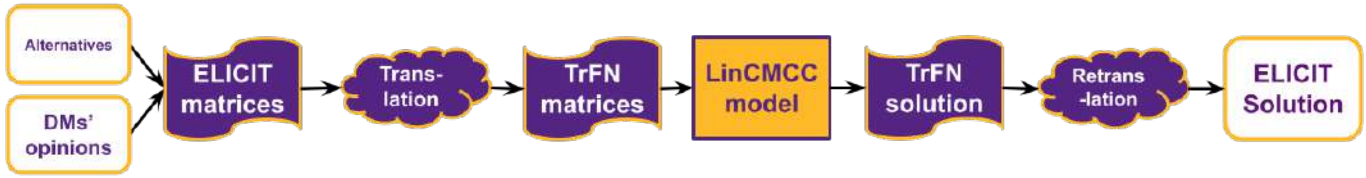

Fig. 3. ELICIT CMCC scheme

where $T(a,b,c,d)$ is the fuzzy envelope of the ELICIT value $[\overline{s}_1,\overline{s}_2]_{\gamma_1,\gamma_2}$, is a bijection whose inverse $\zeta:\mathcal{T}\to\overline{\overline{S}}$ is given by:

$$\zeta:\overline{\overline{S}}\to\mathcal{T}$$
$$T(a,b,c,d)\to[\overline{s}_1,\overline{s}_2]_{\gamma_1,\gamma_2}$$

where

$$\overline{s}_1=\Delta_S(gb)\quad \gamma_1=a-\max\left\{b-\frac{1}{g^2},0\right\}$$
$$\overline{s}_2=\Delta_S(gc)\quad \gamma_2=d-\min\left\{c+\frac{1}{g^2},1\right\}$$

It must be highlighted that the notation $[\overline{s}_1,\overline{s}_2]_{\gamma_1,\gamma_2}$ is used for the sake of clarity, but the reader should keep in mind that, in spite of its formal nature, this notation resembles a linguistic expression.

To aggregate ELICIT values, Labella et al. [7], proposed the use of the fuzzy arithmetic mean operator $A:\mathcal{T}^m\to\mathcal{T}$ defined by

$$A(T_1,T_2,...,T_m)=$$
$$=(\frac{1}{m}\sum_{k=1}^{m}T_k^a,\frac{1}{m}\sum_{k=1}^{m}T_k^b,\frac{1}{m}\sum_{k=1}^{m}T_k^c,\frac{1}{m}\sum_{k=1}^{m}T_k^d)$$

where T_k^t denotes the $t\in\{a,b,c,d\}$ coordinate of the TrFN $T_k, k=1,2,...,m$.

They also proposed a method for ranking ELICIT values based on the method presented by S. Abbasbandy and T. Hajjari in [23]. It transforms the fuzzy envelopes of the ELICIT values, given by a TrFN, into a numerical value called magnitude. The magnitude of the TrFN associated with an ELICIT value is given as:

$$Mag([s_i,s_j]_{\gamma_1,\gamma_2})=Mag(T(a,b,c,d))=$$
$$=\frac{a+5b+5c+d}{12}\in[0,1]$$

To compare two ELICIT values, it suffices to compute the respective magnitudes. According to Labella et al. [7] the higher the magnitude, the larger the ELICIT value.

E. Comprehensive minimum cost consensus

MCC models were introduced by Ben-Arieh and Easton [13] in order to take into account the cost of changing DMs' preferences during a CRP. This proposal considers that the consensus threshold $(1-\mu)$ is the maximum allowed distance between the individual assessments and the collective opinion and the output of the consensus model is the optimal solution which minimizes a certain cost function by assuring the desired consensus. Concretely, for the initial values of the preferences $(o_1,o_2,...,o_m)\in\mathbb{R}$ and a cost vector $(c_1,c_2,...,c_m)\in\mathbb{R}^+$, the corresponding consensus model was defined as follows.

$$\begin{aligned}&\min\sum_{k=1}^{m}c_k|\overline{o}_k-o_k|\\&s.t.\ |\overline{o}_k-\overline{o}|\le\varepsilon,k=1,2,\dots,m.\end{aligned}\qquad\text{(MCC)}$$

where $(\overline{o}_1,\dots,\overline{o}_m)$ are the adjusted opinions of the DMs, $\overline{o}$ represents the group collective opinion computed using a weighted mean operator and ε is the maximum acceptable distance of each DM to the collective opinion.

Lately, Zhang et al. [24] studied how the aggregation operator used to derive the collective opinion can influence the optimal solution. Consequently, they proposed a generalized version of MCC as follows

$$\begin{aligned}&\min\sum_{i=1}^{m}c_i|\overline{o}_i-o_i|\\&s.t.\begin{cases}\overline{o}=F(\overline{o}_1,\dots,\overline{o}_m)\\|\overline{o}_i-\overline{o}|\le\varepsilon,i=1,2,\dots,m,\end{cases}\end{aligned}\qquad\text{(MCC:AO)}$$

where $\overline{o}$ is now calculated using a different aggregation operator $F:\mathbb{R}^m\to\mathbb{R}$.

The main limitations of these kinds of models is the fact that they both neglect a minimum consensus level for the consensus measure, which is key in classical CRP models for GDM. To overcome this drawback, Labella et al. [14] introduced Comprehensive MCC models, which allow taking into account the classical consensus measures when obtaining the optimal solution to the mathematical programming problem:

$$\begin{aligned}&\min\sum_{i=1}^{m}c_i|\overline{o}_i-o_i|\\&s.t.\begin{cases}\overline{o}=F(\overline{o}_1,\dots,\overline{o}_m)\\|\overline{o}_i-\overline{o}|\le\varepsilon,i=1,2,\dots,m\\consensus(\overline{o}_1,\dots,\overline{o}_n)\le\gamma.\end{cases}\end{aligned}\qquad\text{(CMCC)}$$

where $consensus(\cdot)$ represents the desired consensus measure and $\gamma=1-\mu\in]0,1]$ is the corresponding consensus threshold.

III. Comprehensive Minimum Cost Consensus for ELICIT information

MCC models have usually focused on crisp assessments. However, the popularity of linguistic information in GDM is increasing these days, then it is necessary to propose MCC models dealing with this kind of information in order to enrich the research in the area. Therefore, this section is devoted to propose CMCC models for linguistic preferences modeled by ELICIT information.

Note that when linguistic preferences defined in discrete domains are considered, the resolution of the decision process necessarily requires performing approximations. Therefore, one of the main drawbacks of proposing linguistic MCC models may be the loss of information either deadlocks in consensus processes. However, the use of ELICIT information allows manipulating linguistic expressions in a continuous domain without losing information in the process, and consequently, they offer a suitable framework to define such a kind of consensus models.

The general scheme of this proposal is as follows: let us consider a linguistic GDM problem in which $E = \{e_1, e_2, ..., e_m\}$ DMs have to decide in a consensual way which alternative $X = \{x_1, x_2, ..., x_n\}$ is the best solution for a certain problem. To do so, each DM provides a linguistic pairwise comparison matrix, namely Hesitant Fuzzy Linguistic Preference Relation (HFLPR) [25], whose items consist of linguistic assessments modeled using ELICIT information. The ELICIT information contained in these matrices is then translated into the corresponding TrFN. Subsequently, these TrFNs are used as the initial values for the preferences of the DMs in a fuzzy CMCC model. Finally, the modified preferences obtained from computing an optimal solution, represented by TrFNs, are finally retranslated to ELICIT information (see Fig. 3).

To translate the original ELICIT preferences given by DMs into fuzzy numbers, it suffices to calculate their fuzzy envelope (see Def. 2). Let $O_1^{i,j}, O_2^{i,j} ..., O_m^{i,j} \in \mathcal{T}$ $1 \leq i < j \leq n, k = 1, 2, ..., m$ be the original TrFNs obtained from the preferences given by the DMs in form of HFLPR and let $T_1^{i,j}, T_2^{i,j} ..., T_m^{i,j} \in \mathcal{T}$ $1 \leq i < j \leq n, k = 1, 2, ..., m$ be DMs' modified opinions. The cost function for these values is modeled using the linear distance between the modified and initial opinions. As usual, the distance between two TrFNs is given by the function $\delta : \mathcal{T} \times \mathcal{T} \to [0, 1]$ defined by

$$\delta(T_1, T_2) = \frac{1}{4}(|a_1 - a_2| + |b_1 - b_2| + |c_1 - c_2| + |d_1 - d_2|)$$

where $T_1 \equiv (a_1, b_1, c_1, d_1)$, and $T_2 \equiv (a_2, b_2, c_2, d_2)$.

This distance measure allows adapting the classical distance between DMs' opinions and the collective opinion ($0 < \varepsilon \leq 1$) and the consensus measures used in the CMCC models ($0 < \gamma \leq 1$) to the ELICIT CMCC models as follows:

- *ELICIT CMCC model considering a distance-to-collective-based consensus measure:*

$$\min_{T_1^{i,j}, ..., T_m^{i,j} \in \mathcal{T}} \frac{1}{mN} \sum_{k=1}^{m} \sum_{i<j} \delta(T_k^{i,j}, O_k^{i,j})$$
$$s.t. \begin{cases} \overline{T}^{i,j} = A(T_1^{i,j}, T_2^{i,j}, \ldots, T_m^{i,j}), 1 \leq i < j \leq n, \\ \delta(T_k^{i,j}, \overline{T}^{i,j}) \leq \varepsilon, 1 \leq i < j \leq n, k = 1, 2, ..., m, \\ \frac{1}{mN} \sum_{k=1}^{m} \sum_{i<j} \delta(T_k^{i,j}, \overline{T}^{i,j}) \leq \gamma, \end{cases} \quad \text{(ELICIT-CMCC:1)}$$

- *ELICIT CMCC model considering a distance-between-DMs-based consensus measure:*

$$\min_{T_1^{i,j}, ..., T_m^{i,j} \in \mathcal{T}} \frac{1}{mN} \sum_{k=1}^{m} \sum_{i<j} \delta(T_k^{i,j}, O_k^{i,j})$$
$$s.t. \begin{cases} \overline{T}^{i,j} = A(T_1^{i,j}, T_2^{i,j}, \ldots, T_m^{i,j}), 1 \leq i < j \leq n, \\ \delta(T_k^{i,j}, \overline{T}^{i,j}) \leq \varepsilon, 1 \leq i < j \leq n, k = 1, 2, ..., m, \\ \frac{1}{MN} \sum_{k<l} \sum_{i<j} \delta(T_k^{i,j}, T_l^{i,j}) \leq \gamma, \end{cases} \quad \text{(ELICIT-CMCC:2)}$$

where $M = \frac{m(m-1)}{2}$, $N = \frac{n(n-1)}{2}$ and $A : \mathcal{T}^m \to \mathcal{T}$ is the fuzzy arithmetic mean operator.

It should be highlighted that the use of ELICIT information allow both the input and the output of these models being represented in a linguistic expression domain, which makes this proposal a CW model that facilitates the understandability of the results by the involved DMs.

Note that the proposed models use both a nonlinear objective function and nonlinear constraints. Therefore, even though they are suitable for dealing with some experts, they cannot face GDM involving thousands of DMs in few minutes. We will address this issue in future work by proposing linearized versions of these models [26] and the corresponding computational cost analysis will then be performed.

IV. Case study

This section is devoted to show the use of the proposed ELICIT-CMCC approach when applied to a domestic GDM real world problem related to choosing the best streaming platform.

Nowadays, streaming on-line platforms are becoming an alternative to cable TV services because they provide several perks. For instance, streaming platforms are not limited by a predefined TV guide, but the users themselves decide at any given moment what to watch and when to watch it. Additionally, these types of services provide flexible payments and add-free content.

However, there is a wide range of streaming on-line platforms, and choosing the most suitable one could be a complicated task when several people with different interests want to hire one of these services. Furthermore, using the majority rule to decide which service should be hired may be insensible, since some DMs involved could feel unsatisfied with the chosen platform and unlikely to collaborate in the payment of the service. For this reason, obtaining an agreed choice in an interpretable language seems to be the best possible scenario.

Therefore, here it is considered a GDM problem in which three roommates want to decide which is the best online streaming platform to subscribe according to their preferences. The $n = 4$ alternatives are $x_1 =$ Netflix, $x_2 =$ Amazon Prime Video, $x_3 =$ HBO and $x_4 =$ Disney+. The $m = 3$ roommates have provided their opinions using HFLPRs whose linguistic expression domain is

$$S = \{\text{Much Worse(MW)}, \text{Worse(W)}, \text{Slightly Worse(SW)} \\ \text{Equal(E)}, \text{Slightly Better(SB)}, \text{Better(B)}, \text{Much Better(MB)}\}.$$

The initial values provided by the three DMs are:

$$O_1 = \begin{pmatrix} E & W & W & \textit{Bt SW and E} \\ B & E & SB & B \\ B & SW & E & \textit{Bt SB and B} \\ \textit{Bt E and SB} & W & \textit{Bt W and SW} & E \end{pmatrix},$$

$$O_2 = \begin{pmatrix} E & SW & MW & W \\ SB & E & W & SW \\ MB & B & E & SB \\ B & SB & SW & E \end{pmatrix},$$

$$O_3 = \begin{pmatrix} E & SB & B & SW \\ SW & E & \textit{Bt E and SB} & W \\ W & \textit{Bt SW and E} & E & MW \\ SB & B & MB & E \end{pmatrix}.$$

where Bt stands for *between*. These HFLPR are rewritten as ELICIT matrices as follows:

$$O_1 = \begin{pmatrix} (s_3,0) & (s_1,0) & (s_1,0) & [(s_2,0),(s_3,0)] \\ (s_5,0) & (s_3,0) & (s_4,0) & (s_5,0) \\ (s_5,0) & (s_2,0) & (s_3,0) & [(s_4,0),(s_5,0)] \\ [(s_3,0),(s_4,0)] & (s_1,0) & [(s_1,0),(s_2,0)] & (s_3,0) \end{pmatrix},$$

$$O_2 = \begin{pmatrix} (s_3,0) & (s_2,0) & (s_0,0) & (s_1,0) \\ (s_4,0) & (s_3,0) & (s_1,0) & (s_2,0) \\ (s_7,0) & (s_5,0) & (s_3,0) & (s_4,0) \\ (s_5,0) & (s_4,0) & (s_2,0) & (s_3,0) \end{pmatrix},$$

$$O_3 = \begin{pmatrix} (s_3,0) & (s_4,0) & (s_5,0) & (s_2,0) \\ (s_2,0) & (s_3,0) & [(s_3,0),(s_4)] & (s_3,0) \\ (s_3,0) & [(s_2,0),(s_3,0)] & (s_3,0) & (s_0,0) \\ (s_4,0) & (s_5,0) & (s_7,0) & (s_3,0) \end{pmatrix}.$$

and then the corresponding TrFNs are obtained using the mapping ζ^{-1}:

$$O_1 = \begin{pmatrix} T(0.33,0.5,0.5,0.67) & T(0.0,0.17,0.17,0.33) & T(0.0,0.17,0.17,0.33) & T(0.17,0.33,0.5,0.67) \\ T(0.67,0.83,0.83,1.0) & T(0.33,0.5,0.5,0.67) & T(0.5,0.67,0.67,0.83) & T(0.67,0.83,0.83,1.0) \\ T(0.67,0.83,0.83,1.0) & T(0.17,0.33,0.33,0.5) & T(0.33,0.5,0.5,0.67) & T(0.5,0.67,0.83,1.0) \\ T(0.33,0.5,0.67,0.83) & T(0.0,0.17,0.17,0.33) & T(0.0,0.17,0.33,0.5) & T(0.33,0.5,0.5,0.67) \end{pmatrix},$$

$$O_2 = \begin{pmatrix} T(0.33,0.5,0.5,0.67) & T(0.17,0.33,0.33,0.5) & T(0.0,0.0,0.0,0.17) & T(0.0,0.17,0.17,0.33) \\ T(0.5,0.67,0.67,0.83) & T(0.33,0.5,0.5,0.67) & T(0.0,0.17,0.17,0.33) & T(0.17,0.33,0.33,0.5) \\ T(0.83,1.0,1.0,1.0) & T(0.67,0.83,0.83,1.0) & T(0.33,0.5,0.5,0.67) & T(0.5,0.67,0.67,0.83) \\ T(0.67,0.83,0.83,1.0) & T(0.5,0.67,0.67,0.83) & T(0.17,0.33,0.33,0.5) & T(0.33,0.5,0.5,0.67) \end{pmatrix},$$

$$O_3 = \begin{pmatrix} T(0.33,0.5,0.5,0.67) & T(0.5,0.67,0.67,0.83) & T(0.67,0.83,0.83,1.0) & T(0.17,0.33,0.33,0.5) \\ T(0.17,0.33,0.33,0.5) & T(0.33,0.5,0.5,0.67) & T(0.33,0.5,0.67,0.83) & T(0.0,0.17,0.17,0.33) \\ T(0.0,0.17,0.17,0.33) & T(0.17,0.33,0.5,0.67) & T(0.33,0.5,0.5,0.67) & T(0.0,0.0,0.0,0.17) \\ T(0.5,0.67,0.67,0.83) & T(0.67,0.83,0.83,1.0) & T(0.83,1.0,1.0,1.0) & T(0.33,0.5,0.5,0.67) \end{pmatrix}.$$

To obtain the results of the optimization problem we have used the software R, concretely the package *nloptr* [27] which allow to approximately solve nonlinear optimization problems with nonlinear constraints. If the consensus threshold is established as 0.8 ($\gamma = 0.2$) and the distance between the DMs and the collective opinion is $\varepsilon = 0.2$, the optimal solution obtained for the proposed CMCC model is as follows:

$$T_1 = \begin{pmatrix} T(0.33,0.5,0.5,0.67) & T(0.37,0.58,0.72,0.75) & T(0.09,0.53,0.68,0.81) & T(0.34,0.61,0.63,0.69) \\ T(0.25,0.28,0.42,0.63) & T(0.33,0.5,0.5,0.67) & T(0.08,0.19,0.4,0.84) & T(0.03,0.07,0.12,0.63) \\ T(0.19,0.32,0.47,0.91) & T(0.16,0.6,0.81,0.92) & T(0.33,0.5,0.5,0.67) & T(0.19,0.58,0.86,0.9) \\ T(0.31,0.37,0.39,0.66) & T(0.37,0.88,0.93,0.97) & T(0.1,0.14,0.42,0.81) & T(0.33,0.5,0.5,0.67) \end{pmatrix},$$

$$T_2 = \begin{pmatrix} T(0.33,0.5,0.5,0.67) & T(0.01,0.33,0.62,0.68) & T(0.3,0.34,0.55,0.67) & T(0.01,0.34,0.63,0.69) \\ T(0.32,0.38,0.67,0.99) & T(0.33,0.5,0.5,0.67) & T(0.24,0.36,0.61,0.84) & T(0.23,0.43,0.62,0.81) \\ T(0.33,0.45,0.66,0.7) & T(0.16,0.39,0.64,0.76) & T(0.33,0.5,0.5,0.67) & T(0.05,0.22,0.53,0.8) \\ T(0.31,0.37,0.66,0.99) & T(0.19,0.38,0.57,0.77) & T(0.2,0.47,0.78,0.95) & T(0.33,0.5,0.5,0.67) \end{pmatrix},$$

$$T_3 = \begin{pmatrix} T(0.33,0.5,0.5,0.67) & T(0.1,0.29,0.37,0.38) & T(0.32,0.5,0.68,0.81) & T(0.06,0.17,0.23,0.33) \\ T(0.62,0.63,0.71,0.9) & T(0.33,0.5,0.5,0.67) & T(0.63,0.74,0.75,0.82) & T(0.08,0.11,0.23,0.52) \\ T(0.19,0.32,0.5,0.68) & T(0.18,0.25,0.26,0.37) & T(0.33,0.5,0.5,0.67) & T(0.09,0.34,0.86,0.88) \\ T(0.67,0.77,0.83,0.94) & T(0.48,0.77,0.89,0.92) & T(0.12,0.14,0.66,0.91) & T(0.33,0.5,0.5,0.67) \end{pmatrix}.$$

Then, the corresponding collective opinion is translated into ELICIT values. For the sake of space, here just the upper triangle of the corresponding matrix is shown:

$$\overline{T}^{1,2} = [(SW,0.41),(E,0.43)]_{(-0.07,-0.14)}$$
$$\overline{T}^{1,3} = [(E,-0.25),(SB,-0.19)]_{(-0.06,-0.04)}$$
$$\overline{T}^{1,4} = [(SW,0.24),(E,-0.02)]_{(-0.07,-0.09)}$$
$$\overline{T}^{2,3} = [(E,-0.44),(SB,-0.49)]_{(0.06,0.08)}$$
$$\overline{T}^{2,4} = [(W,0.23),(SW,-0.05)]_{(0.07,0.16)}$$
$$\overline{T}^{3,4} = [(SW,0.29),(SB,0.48)]_{(-0.1,-0.05)}$$

The collective values of the alternatives are:

$$x_1 : Bt\ (SW, 0.46)^{-0.065} and\ (E, 0.41)^{-0.09},$$
$$x_2 : Bt\ (SW, 0.12)^{0.09}\ and\ (E, 0.02)^{0.105},$$
$$x_3 : Bt\ (SW, 0.32)^{-0.048}\ and\ (SB, -0.27)^{-0.02},$$
$$x_4 : Bt\ (E, -0.14)^{-0.005}\ and\ (SB, 0.08)^{0.032}.$$

Therefore, by computing the magnitude of each ELICIT value, the ranking of the alternatives is: $x_4 > x_3 > x_1 > x_2$. In other words, choosing the alternative $x_4 =$ Disney+ is the best option from a consensual point of view.

V. Comparative Analysis

In this section the performance of the introduced ELICIT CMCC model is compared with two different proposals: the consensus model for ELICIT information introduced by Labella et al. [8] and Rodríguez et al. CRP for CLEs [9]. To do so, the decision problem introduced in the previous section will be solved using these two proposals and then the cost of the necessary changes to obtain the respective solutions will be computed in order to evaluate the out performance of ELICIT-CMCC:2 model. Simulations of these consensus models have been carried out using the consensus software AFRYCA [28], which also includes a graphical visualization tool based on multidimensional scaling.

Labella et al. [8] model has been evaluated by considering two different consensus levels 0.8 and 0.9, that is $\gamma = 0.2$ and $\gamma = 0.1$ and a maximal number of discussion rounds equal to

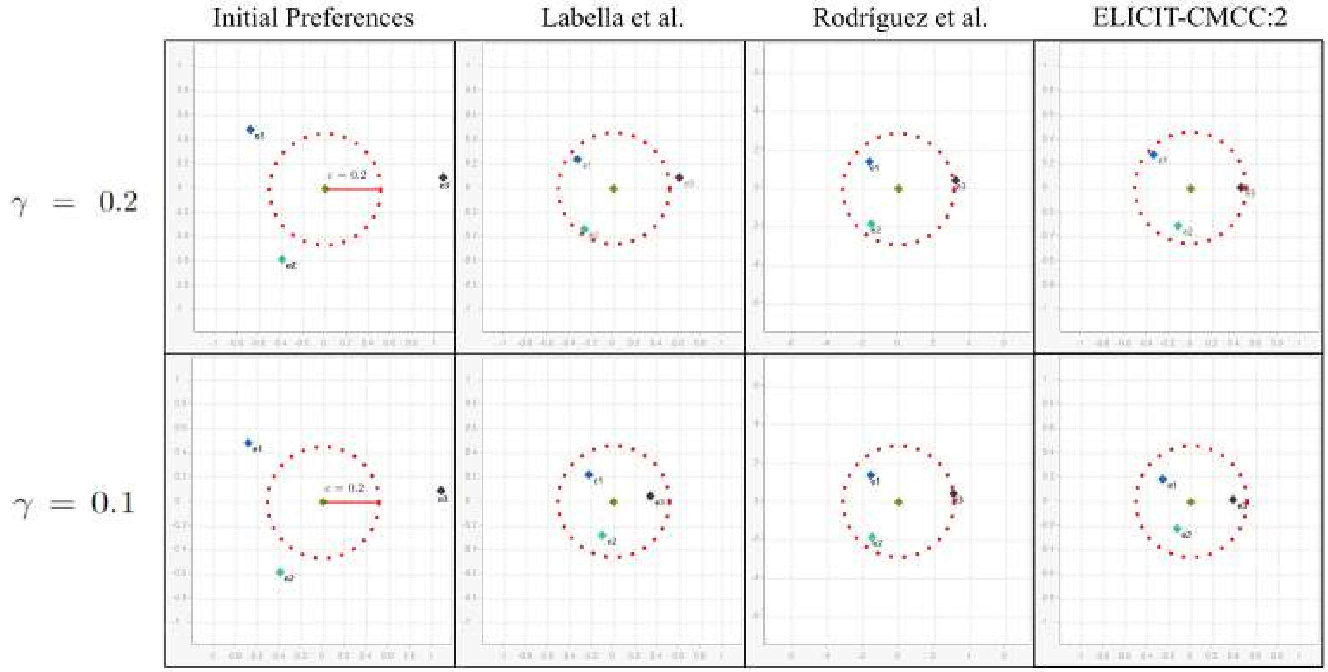

Fig. 4. Graphical visualization regarding the DMs' preferences in the different simulations and consensus models.

5. In the first simulation, the consensus approach achieves a consensus degree of 0.79 ($\gamma = 0.19$) in one discussion round, while in the second simulation the consensus model does not achieve the desired consensus, but a level of agreement equal to 0.87 ($\gamma = 0.13$) in five rounds (see Table I). Fig. 4 shows the graphical representation of the DMs' preferences in the last rounds of the consensus process in both simulations. Regarding the distance between experts and collective opinion ε, the figure clearly shows that experts are much closer to collective opinion in ELICIT CMCC: 2.

Rodríguez et al. [9] CRP has also been evaluated by considering the consensus levels 0.8 and 0.9 ($\gamma = 0.2$ and $\gamma = 0.1$) and a maximal number of discussion rounds equal to 5. The corresponding graphical representation can also be found in Fig. 4. In the first simulation, the model achieves a consensus level of 0.83 ($\gamma = 0.17$) in 2 discussion rounds, whereas in the second simulation the consensus model does not achieve the desired consensus but a level of agreement equal to 0.85 ($\gamma = 0.15$) in 5 rounds (see Table I). When using this approach, the distance between experts and collective opinion is also greater than the obtained in ELICIT-CMCC:2.

As expected, the costs obtained in ELICIT-CMCC:2 (0.03 and 0.05) are lower than the costs of Labella et al. [8] (0.23 and 0.25) and Rodríguez et al. [9] (0.26 and 0.25).

TABLE I
COMPARATIVE RESULTS FOR LABELLA ET AL. [8], RODRÍGUEZ ET AL. [9] AND ELICIT-CMCC:2

Consensus model	***Consensus threshold*** (γ)	***Distance to collective*** (ε)	***Cost***	***Rounds* Required**
ELICIT CMCC 2	0.2 0.1	0.2 0.2	0.03 0.05	- -
Labella et al. [8]	0.2(0.19) 0.1(0.13)	0.33 0.28	0.23 0.25	1 5
Rodríguez et al. [9]	0.2 (0.17) 0.1(0.15)	0.28 0.28	0.26 0.25	2 5

VI. CONCLUSIONS AND FUTURE RESEARCH

This contribution has developed two linguistic CMCC models based on ELICIT information, namely ELICIT-CMCC:1 and ELICIT-CMCC:2 in which consensus measures based on distance between experts and collective or distance between experts are respectively considered.

Using the properties of ELICIT values, which allow performing precise computations with linguistic expressions without any information loss, we have proposed two CW consensus models for GDM for which the obtained solution satisfies the following properties.

- It is expressed in a linguistic domain,
- It minimizes the cost of moving experts' preferences,
- The distance between the modified opinions and the collective opinion is lower than ε,
- The obtained consensus level is greater than $1 - \gamma$.

The use of this proposal has been shown in a case study and the ELICIT-CMCC approach has been also compared with the consensus models proposed by Labella et al. [14] and Rodríguez et al. [9].

Undoubtedly, this contribution opens up several new research lines that should be covered in the future. First, here we have considered that DMs' preferences are elicited using pairwise comparison matrices, but it would be possible to analyze how to provide ELICIT-CMCC models for other types of linguistic structures such as utility linguistic vectors. In addition, it would be interesting to analyze how to define linearized versions for the models proposed here, especially if we pretend to cover Large-Scale GDM problems in which the number of variables and constraints would be high. Additionally, we would like to perform a computational cost analysis of both the proposed model and the corresponding linearized version. Furthermore, this proposal has considered that the preferences are aggregated using the fuzzy arithmetic mean operator, but there is a huge variety of these aggregation functions that could be included in the ELICIT-CMCC approach in the future. Another future work should be devoted to provide a sensitive analysis of the impact of the parameters γ and ϵ in the decision process. Finally, the most important research line that emerges from this proposal is related to the definition of metrics to compare consensus models. Our comparative analysis shows that ELICIT-CMCC models are much better in terms of efficiency (lower cost, and better values for γ and ε) than two classical CRPs in which ELICIT information can be used as initial values of the preferences. This suggests the possibility of developing an objective metric based on ELICIT-CMCC models which allows comparing CRPs for ELICIT information in order to determine the one with the best performance.

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REFERENCES

[1] S. V. Kovalchuk, V. Krotov, P. A. Smirnov, D. A. Nasonov, and A. N. Yakovlev, "Distributed data-driven platform for urgent decision making in cardiological ambulance control," *Future Generation Computer Systems-the International Journal of Escience*, vol. 79, pp. 144–154, 2018.

[2] Q. Q. Long, "Data-driven decision making for supply chain networks with agent-based computational experiment," *Knowledge-Based Systems*, vol. 141, pp. 55–66, 2018.

[3] I. Palomares, R. M. Rodríguez, and L. Martínez, "An attitude-driven web consensus support system for heterogeneous group decision making," *Expert Systems with Applications*, vol. 40, no. 1, pp. 139–149, 2013.

[4] Y. Sun, S. He, and J. Leu, "Syndicating web services: A qos and user-driven approach," *Decision Support Systems*, vol. 43, 2007.

[5] L. Martínez, D. Ruan, F. Herrera, and E. Herrera-Viedma, "Linguistic decision making: Tools and applications preface," *Information Sciences*, vol. 179, no. 14, pp. 2297–2298, JUN 27 2009.

[6] L. Martínez, R. M. Rodríguez, and F. Herrera, *The 2-tuple Linguistic Model*. Springer International Publishing, 2015.

[7] Á. Labella, R. M. Rodríguez, and L. Martínez, "Computing with comparative linguistic expressions and symbolic translation for decision making: Elicit information," *IEEE Transactions on Fuzzy Systems*, vol. 28, no. 10, pp. 2510–2522, 2019.

[8] Á. Labella, R. M. Rodríguez, A. A. Alzahrani, and L. Martínez, "A consensus model for extended comparative linguistic expressions with symbolic translation," *Mathematics*, vol. 8, no. 12, p. 2198, 2020.

[9] R. M. Rodríguez, Á. Labella, M. Sesma-Sara, H. Bustince, and L. Martínez, "A cohesion-driven consensus reaching process for large scale group decision making under a hesitant fuzzy linguistic term sets environment," *Computers & Industrial Engineering*, vol. 155, p. 107158, 2021.

[10] Z. Zhang and Z. Li, "Personalized individual semantics-based consistency control and consensus reaching in linguistic group decision making," *IEEE Transactions on Systems, Man, and Cybernetics: Systems*, pp. 1–13, 2021.

[11] Z. Zhang, Z. Li, and Y. Gao, "Consensus reaching for group decision making with multi-granular unbalanced linguistic information: A bounded confidence and minimum adjustment-based approach," *Information Fusion*, vol. 74, pp. 96–110, 2021.

[12] I. Palomares, F. Estrella, L. Martínez, and F. Herrera, "Consensus under a fuzzy context: Taxonomy, analysis framework AFRYCA and experimental case of study," *Information Fusion*, vol. 20, pp. 252–271, 2014.

[13] D. Ben-Arieh and T. Easton, "Multi-criteria group consensus under linear cost opinion elasticity," *Decision Support Systems*, vol. 43, no. 3, pp. 713–721, 2007.

[14] A. Labella, H. Liu, R. M. Rodríguez, and L. Martínez, "A cost consensus metric for consensus reaching processes based on a comprehensive minimum cost model," *European Journal of Operational Research*, vol. 281, pp. 316–331, 2020.

[15] D. García-Zamora, A. Labella, R. M. Rodríguez, and L. Martínez, "Nonlinear preferences in group decision-making. Extreme Values Amplifications and Extreme Values Reductions," *International Journal of Intelligent Systems*, vol. 36, no. 11, pp. 6581–6612, Jul. 2021.

[16] R. M. Rodríguez, A. Labella, G. D. Tré, and L. Martínez, "A large scale consensus reaching process managing group hesitation," *Knowledge-Based Systems*, vol. 159, pp. 86–97, 2018.

[17] I. Palomares, L. Martínez, and F. Herrera, "A consensus model to detect and manage noncooperative behaviors in large-scale group decision making," *IEEE Transactions on Fuzzy Systems*, vol. 22, no. 3, pp. 516–530, 2014.

[18] L. A. Zadeh, "The concept of a linguistic variable and its application to approximate reasoning, part i, ii, iii," *Information Sciences*, vol. 8,8,9, pp. 199 – 249, 301–357, 43–80, 1975.

[19] ——, "Fuzzy sets," in *Fuzzy sets, fuzzy logic, and fuzzy systems: selected papers by Lotfi A Zadeh*. World Scientific, 1996, pp. 394–432.

[20] R. Rodríguez, A. Labella, and L. Martínez, "An overview on fuzzy modelling of complex linguistic preferences in decision making," *International Journal of Computational Intelligence Systems*, vol. 9, pp. 81–94, 2016 2016.

[21] R. M. Rodríguez, L. Martínez, and F. Herrera, "A group decision making model dealing with comparative linguistic expressions based on hesitant fuzzy linguistic term sets," *Information Sciences*, vol. 241, no. 1, pp. 28–42, 2013.

[22] R. M. Rodríguez, L. Martínez, V. Torra, Z. Xu, and F. Herrera, "Hesitant fuzzy sets: state of the art and future directions," *International Journal of Intelligent Systems*, vol. 29, no. 6, pp. 495–524, 2014.

[23] S. Abbasbandy and T. Hajjari, "A new approach for ranking of trapezoidal fuzzy numbers," *Computers & Mathematics with Applications*, vol. 57, no. 3, pp. 413–419, 2009.

[24] G. Zhang, Y. Dong, Y. Xu, and H. Li, "Minimum-cost consensus models under aggregation operators," *IEEE Transactions on Systems, Man and Cybernetics-Part A: Systems and Humans*, vol. 41, no. 6, pp. 1253–1261, 2011.

[25] B. Zhu and Z. Xu, "Consistency measures for hesitant fuzzy linguistic preference relations," *IEEE Transactions on Fuzzy Systems*, vol. 22, no. 1, pp. 35–45, Feb 2014.

[26] R. M. Rodríguez, Á. Labella, B. Dutta, and L. Martínez, "Comprehensive minimum cost models for large scale group decision making with consistent fuzzy preference relations," *Knowledge-Based Systems*, vol. 215, p. 106780, 2021.

[27] S. G. Johnson, "The nlopt nonlinear-optimization package," *version 1.2.2.3*, 2021. [Online]. Available: https://cran.r-project.org/package=nloptr

[28] Á. Labella, F. Estrella, and L. Martínez, "AFRYCA 2.0: an improved analysis framework for consensus reaching processes," *Progress in Artificial Intelligence*, vol. 6, p. 181–194, 2017.