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Personalized individual semantics in computing with words for supporting linguistic group decision making. An application on consensus reaching

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ABSTRACT

In group decision making (GDM) dealing with Computing with Words (CW) has been highlighted the importance of the statement, *words mean different things for different people*, because of its influence in the final decision. Different proposals that either grouping such different meanings (uncertainty) to provide one representation for all people or use multi-granular linguistic term sets with the semantics of each granularity, have been developed and applied in the specialized literature. Despite these models are quite useful they do not model individually yet the different meanings of each person when he/she elicits linguistic information. Hence, in this paper a personalized individual semantics (PIS) model is proposed to personalize individual semantics by means of an interval numerical scale and the 2-tuple linguistic model. Specifically, a consistency-driven optimization-based model to obtain and represent the PIS is introduced. A new CW framework based on the 2-tuple linguistic model is then defined, such a CW framework allows us to deal with PIS to facilitate CW keeping the idea that words mean different things to different people. In order to justify the feasibility and validity of the PIS model, it is applied to solve linguistic GDM problems with a consensus reaching process.

1. Introduction

Human beings usually employ words in most of their computing and reasoning processes without the necessity of any precise number. Computing with words (CW) is a methodology in which the objects of computation are words and propositions drawn from a natural language [49,50] that arises to emulate such human behaviors. Hence a crucial feature of CW is that its processes deal with linguistic inputs to obtain linguistic outputs easy to understand by human beings. Different computing schemes have been proposed for CW that could be summarized in Fig. 1. Yager [48] points out the importance of the translation and retranslation processes to achieve the aims of the CW.

It is important to remark that CW involves a wide-ranging ramifications and applications from learning to decision making passing by many others [13,15,23,39,40]. Our interest in this paper is focused on the use of CW in decision making [28]. Specifically on group decision making (GDM) because its use implies another key and controversial point about CW, that it is the fact that *words mean different things for different people* [1,16,29,30]. In order to deal with previous fact that increases the difficulty of managing the uncertainty of linguistic information, two mainstreams have been developed in the literature:

1. The use of type-2 fuzzy sets based on low and upper possibility distributions with a third dimension in between [29], that group all meanings from people in just one representation function and,
2. The use of multi-granular linguistic models [14,19,33] in which multiple linguistic term sets can be used by experts according to either their degree of knowledge or their comfort or their similarity with the semantics of each granularity.

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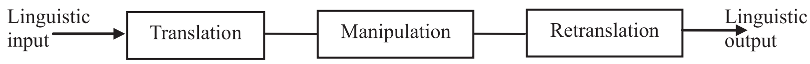

Fig. 1. Yager's CW scheme.

In spite of both previous methods are quite useful to deal with the multiple meanings of words and have been also widely used for CW in multiple different problems, they do not represent yet the specific semantics of each individual. For example, when reviewing an article, two referees both think this article is "*Good*", but the term "*Good*" often has different numerical meanings for these two referees. Hence, in this paper a personalized individual semantics (PIS) model is proposed to customize individual semantics by means of an interval numerical scale [6,12] and the 2-tuple linguistic model [18]. In order to do so, this paper develops two main proposals:

(a) A new model to represent PIS, such that it will be based on the interval numerical scale because of its features to deal with different linguistic representations in a precise way [6,12].
(b) A framework for CW dealing with PIS, based on the 2-tuple linguistic model [27], including personalized 2-tuple linguistic operators are proposed, because of its good features for managing linguistic information in CW processes [38]. This framework will cope with PIS and redesign the CW phases pointed out in Fig. 1 to obtain customized accurate linguistic results easy to interpret and understand by individuals.

There are a lot of researches regarding GDM problems using linguistic preference relations, such as aggregation operators [3], consistency measures [8,10], consensus models [9,20,34] and so on. In order to justify the feasibility and validity of the PIS model, it will be applied to a linguistic GDM problem with a consensus reaching process, by defining the concept of the *individual linguistic understanding*.

The remainder of this paper is arranged as follows. Section 2 introduces a basic description of the 2-tuple linguistic model, the numerical scale and preference relations. Section 3 introduces a consistency-driven optimization-based model to obtain the interval numerical scale of PIS for decision makers in linguistic GDM problems. Section 4 proposes a new CW framework based on the 2-tuple linguistic model for dealing with PIS. Section 5 presents a consensus reaching process for linguistic GDM problems with PIS. Section 6 then concludes this paper.

2. Preliminaries

This section introduces the basic necessary knowledge to understand our proposals, regarding the 2-tuple linguistic model, the numerical scale and preference relations.

2.1. The 2-tuple linguistic model

The 2-tuple linguistic representation model, presented in Herrera and Martínez [18] represents the linguistic information by a 2-tuple $(s_i, \alpha) \in \bar{S} = S \times [-0.5, 0.5)$, where $s_i \in S$ and $\alpha \in [-0.5, 0.5)$. Formally, let $S = \{s_i | i = 0, 1, 2, \ldots, g\}$ be a linguistic term set and $\beta \in [0, g]$ be a value representing the result of a symbolic aggregation operation. The 2-tuple that expresses the equivalent information to β is then obtained as:

$$\Delta : [0, g] \to S \times [-0.5, 0.5), \quad (1)$$

where

$$\Delta(\beta) = (s_i, \alpha), with \begin{cases} s_i, i = round(\beta) \\ \alpha = \beta - i, \alpha \in [-0.5, 0.5) \end{cases}. \quad (2)$$

Function Δ, it is a one to one mapping whose inverse function $\Delta^{-1} : \bar{S} \to [0, g]$ is defined as $\Delta^{-1}(s_i, \alpha) = i + \alpha$. When $\alpha = 0$ in (s_i, α) is then called simple term.

In [18] it was also defined a computational model for linguistic 2-tuples in which different operations were introduced:

(1) A 2-tuple comparison operator: Let (s_k, α) and (s_l, γ) be two 2-tuples. Then:
  (i) if $k < l$, then (s_k, α) is smaller than (s_l, γ).
  (ii) if $k = l$, then
    (a) if $\alpha = \gamma$, then (s_k, α), (s_l, γ) represents the same information.
    (b) if $\alpha < \gamma$, then (s_k, α) is smaller than (s_l, γ).
(2) A 2-tuple negation operator:
$Neg((s_i, \alpha)) = \Delta(g - (\Delta^{-1}(s_i, \alpha)))$.
(3) Several 2-tuple aggregation operators have been developed (see [18,31]).

2.2. Numerical scale to extend the 2-tuple linguistic model

Dong et al. [11,12] extended the 2-tuple linguistic model by the numerical scale and the interval numerical scale for integrating different linguistic models and increasing the accuracy of the 2-tuple linguistic computational model.

(1) Numerical scale

The concept of the numerical scale was introduced in [11] for transforming linguistic terms into real numbers:

Definition 1. [11] Let $S = \{s_i | i = 0, 1, 2, \ldots, g\}$ be a linguistic term set, and R be the set of real numbers. The function: NS: $S \to R$ is defined as a numerical scale of S, and $NS(s_i)$ is called the numerical index of s_i. If the function NS is strictly monotone increasing, then NS is called an ordered numerical scale.

Definition 2. [11] Let $S, \bar{S}$ and NS be as before. The numerical scale $\overline{NS}$ on $\bar{S}$ for $(s_i, \alpha) \in \bar{S}$, is defined by

$$\overline{NS}((s_i, \alpha)) = \begin{cases} NS(s_i) + \alpha \times (NS(s_{i+1}) - NS(s_i)), \alpha \geq 0 \\ NS(s_i) + \alpha \times (NS(s_i) - NS(s_{i-1})), \alpha < 0 \end{cases}. \quad (3)$$

To simplify the notation, $\overline{NS}$ will also be denoted as NS in this paper.

In [11] NS was introduced as a a family of functions, that usually are ordered functions, if so it was proved that its inverse NS^{-1} exists. For example, setting $NS(s_i) = \Delta^{-1}(s_i)$ (i.e., $NS(s_0) = 0, NS(s_1) = 1, \ldots, NS(s_g) = g$) yields the 2-tuple linguistic model [18].

(2) Interval numerical scale

The concept of the interval numerical scale [12] extends the numerical scale model to transform linguistic terms into numerical interval values:

Definition 3. [12] Let $S = \{s_i | i = 0, 1, 2, \ldots, g\}$ be a linguistic term set, and let $M = \{[A_L, A_R] | A_L, A_R \in [0, 1], A_L \leq A_R\}$ be a set of interval values in [0, 1]. The function INS: $S \to M$ is defined as an interval numerical scale of S, and $INS(s_i)$ is called the interval numerical index of s_i.

If $INS(s_i) = [A_L^i, A_R^i]$, then the functions INS_L and INS_R are defined as follows: $INS_L(s_i) = A_L^i$ and $INS_R(s_i) = A_R^i$. The interval numerical scale INS is ordered if $INS_L(s_i) < INS_L(s_{i+1})$ and $INS_R(s_i) < INS_R(s_{i+1})$ for $i = 0, 1, \ldots, g - 1$.