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A web tool to support decision making in the housing market using hesitant fuzzy linguistic term sets

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ABSTRACT

In this paper we present a linguistic multiple-expert multi-criteria decision making model and a web tool to support it, that is centred on the housing market. The web tool is integrated with the usual catalogue of resources for rental or for sale, enriched with the possibility of ranking a subset of properties according to the client's preferences and the internal knowledge associated to the properties. Usually the description of a property is quantitative, thought in our case we add qualitative information corresponding to assessments made by housing agents. These agents are considered experts in the market conditions.

We apply the 2-tuple linguistic representation model to keep accuracy in the processes of Computing with Words and the hesitant fuzzy linguistic term sets to qualify in situations of uncertainty and hesitation in the assessments. The software helps the agents in the process of the elicitation of the linguistic expression based on the fuzzy linguistic approach and the use of context-free grammars, and the web clients in the decision of visiting a property.

1. IntroductionIntroduction

Every day people are challenged with multiple acts of decision. It is a natural human activity that is prompt to be subjective in its basis, but also to be uncertain and imprecise. Sometimes we are not aware of the implicit complexity of a problem, except when we try to make decisions with computational models. Problems defined under uncertain conditions are common in real world, but quite challenging to be modelled in a computer program due to the difficulty of dealing with uncertain information. Computing with Words (CW) [30] is a methodology for reasoning and computing with perceptions rather than measurements. CW is able to empower applications that involve people expressing their preferences which happens in linguistic Decision Making (DM): the experts assess the potential of an alternative through qualitative values rather than quantitative ones.

Some models have been proposed to operate with linguistic information [1,6,16]. In this work we operate with the fuzzy linguistic approach, that represents qualitative aspects as linguistics values by means of linguistics variables [29]. These models are preferable because experts are allowed to evaluate closer to natural language and the way people reason. Criteria in different problems may vary, for example, if we describe a car, the criteria would involve price, fuel consumption or comfort. On the other hand, it is sometimes difficult to give an opinion as an exact single label, though we could allow to work with some possible set of values for decision makers.

To manage linguistic information in DM a well known computational model that carries out CW processes without loss of information is the 2-tuple Linguistic Computational Model [8]. This model uses a pair of values called linguistic 2-tuple to represent the linguistic information. Many extensions to the 2-tuple linguistic model have been developed: to deal with unbalanced linguistic information [11] where the linguistic labels in the terms set are not evenly distributed around a central term, or to deal with multi-granular label sets [10]. A generalization of the 2-tuple representation, the proportional 2-tuple models were developed by Wang and Hao in [24]. Also, Dong et al. [3,4] explored the concept of numerical scale, which extends the linguistic 2-tuple and the proportional 2-tuple.

Recently it has been enabled in DM problems the possibility of provide inaccurate rates and comparative linguistic expressions by means of the use of a context-free grammar represented by a hesitant fuzzy linguistic term set (HFLTS) [13,18]. This way to deal with uncertainty and hesitation in the context of fuzzy decision making, derives from the original idea of Torra's hesitant fuzzy sets [22], has been applied in many recent works [2,12–15,17,19,20,26,25,23,31,32].

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Particularly, the group decision making (GDM) problem is an area of application of CW to achieve a collective decision, that could benefit from the use of hesitant linguistic assessments [19] or consensus models [5].

In the housing market, a common problem is to describe a property accurately. When the owner fills the description form to upload a new record, the description he/she makes is usually over positive deliberately omitting deficiencies. The price tends to be too high because the owner lacks the knowledge of the area. Additionally the customer could get disappointed when visit the place because it may not fulfil the expectations. The first issue could be resolved with the counselling to the owner. For example, in some Real Estate agencies, a new order of for sale or to rent is taken by a realtor that describes the property after interviewing the owner and advises on the price. In our knowledge for the second issue, there is currently no automated solution to advice a buyer about what property should visit in person according the expectations.

The agents of a Real Estate agency are experts in the housing market and can be involved in a multi-expert multi-criteria decision making model. Criteria are attributes that helps in the description of a house. The benefit from the application of the model could consist in the valuation of candidates, in this case, a list of properties (houses, flats, garages, et.). Usually agencies have an online catalogue, offering properties for sale and to rent to online customers around the world to increase the opportunities of business. Data and customers are online, thus a convenient solution would imply a web tool integrated within the catalogue.

The aim of this paper is to present a practical application in decision making of a 2-tuple linguistic fuzzy model with hesitant information. It represents a Real Estate web site with information of properties for sale or to rent. The novelty of the portal is the possibility of using linguistic expressions to assess a set of qualitative criteria. We have added eight criteria not so commonly used to describe the property, but that we think of relevance to the client following the suggestions of Real Estate agents. The evaluation of the properties is done by the realtors who possess the expertise over the housing market. DM processes that run over the server portal will use this internal information to propose a visitation order to its web clients based on their preferences. Also, a client of a Real Estate web site could assign a preference degree to each criteria in its profile area. The rest of this paper is structured as follows. In Section 2, some preliminaries related with the representation of qualitative data and the grammar used to evaluate are reviewed. In Section 3, a Multi-Criteria Multi-Expert Decision Making problem for the housing market is presented based on 2-tuple fuzzy representation of hesitant expressions. In Section 4, an illustrative example is presented. In Section 5, some conclusions are given.

2. Preliminaries

The fuzzy linguistic approach manipulate qualitative information by using linguistic variables as a representation of those values. Words are not numbers and thus they are more imprecise, but thanks to linguistic models, computations can be carried out using this type of information. In the literature we find a methodology to apply CW in decision making [6], that was introduced by Zadeh in the seminal paper [28] and in the definition of a linguistic variable [29]. We have chosen to apply the 2-tuple linguistic computational model as it represents a transformation of a linguistic variable which is suitable for computations without any lost of information.

In this section we give some general definitions of the 2-tuple representation model and a description of how the HFLTS enables a flexible way of elicit linguistic information.

2.1. A computational 2-tuple fuzzy linguistic model

A linguistic variable can take values only in a finite set of eligible values that are defined by the linguistic term set $S = \{s_0, \ldots, s_g\}$, in which $g+1$ is called the cardinality of S and usually is an odd number. The more terms in S the more precise an evaluation could be, but on the contrary, it also imposes hesitation to the expert. The linguistic terms $s_k \in S$ are defined by triangular membership functions uniformly distributed. These assumptions guarantee that the 2-tuple linguistic computational model [8] is precise and effective.

Definition 1. [8] Let S be a linguistic term set, and $\beta \in [0, g]$. Then the 2-tuple is defined as:

$$\Delta : [0, g] \to S \times [-0.5, 0.5)$$
$$\Delta(\beta) = (s_i, \alpha), \text{ with } \begin{cases} s_i, i = round(\beta), \\ \alpha = \beta - i \end{cases} \quad (1)$$

The 2-tuple becomes a equivalent representation of any term $s_i \in S$. The inverse function $\Delta^{-1} : S \times [-0.5, 0.5) \to [0, g]$ is defined in [8] by $\Delta^{-1}(s_i, \alpha) = i + \alpha = \beta$. The value of $\alpha \in [-0.5, 0.5)$ it is known as the symbolic translation. So, a linguistic term $s_i \in S$ transforms into $(s_i, 0)$ in CW processes.

When rating two alternatives assessed with a linguistic variable represented with a 2-tuple, a comparison rule is needed. We find in [8] a valid comparison rule:

1 if $n < m$, then (s_n, α_1) is smaller than (s_m, α_2)
2 if $n = m$, then

(a) if $\alpha_1 = \alpha_2$, then (s_n, α_1) and (s_m, α_2) are the same
(b) if $\alpha_1 < \alpha_2$, then (s_n, α_1) is smaller than (s_m, α_2)
(c) if $\alpha_1 > \alpha_2$, then (s_n, α_1) is bigger than (s_m, α_2)

To aggregate 2-tuples, the arithmetic mean can be adapted to be applied to the 2-tuple representation. Let $x = \{(s_1, \alpha_1), \ldots, (s_n, \alpha_n)\} = \{\beta_1, \ldots, \beta_n\}$ be a set of linguistic values represented as 2-tuple, W a weighting vector $(\{w_i / i = 1, \ldots, n\})$, and W' its normalised version $(\{w'_i / i = 1, \ldots, n\})$, i.e. $\sum_{i=1}^{n} w'_i = 1$. The arithmetic weighed extended mean $\bar{x}^e$ is defined as:

$$\bar{x}^e(x) = \Delta\left(\frac{\sum_{i=1}^{n} \Delta^{-1}(s_i, \alpha_i) \cdot w_i}{\sum_{i=1}^{n} w_i}\right) = \Delta\left(\frac{1}{n}\sum_{i=1}^{n} \beta_i w'_i\right). \quad (2)$$

Example 1. A linguistic term set with five linguistic terms can be as: $S = \{nothing, little, middle, high, very\ high\}$. A linguistic variable ϑ representing the ambient noise of a neighbourhood could be valued at midnight as *little*. So $\vartheta = s_1$, but in operations the 2-tuple $(s_1, 0)$, or $\beta = 1$, will be used.

2.2. Hesitant fuzzy linguistic term set

In situations where is usual to handle imprecise information, it is needed a solution to model hesitation in the elicitation of linguistic information. In a quantitative setting, the concept of hesitant fuzzy set (HFS) was introduced in [22] to allow decision makers the consideration of several values to determine the membership of an element to a set. The concept of HFS have proved to be applicable to DM, evaluation and clustering techniques [20]. To be used in linguistic fuzzy decision making situations, its extension known as HFLTS was presented in [18]. Afterwards, many researchers have apply the concept of HFLTS [2,12–15,17,19,25,26,31,32].

Definition 2. [18] Let $S = \{s_0, \ldots, s_t\}$ be a fixed set of linguistic term set. A hesitant fuzzy linguistic term set (HFLTS) H, is an ordered finite subset of the consecutive linguistic terms of S.