LINGUISTIC SENSORY EVALUATION MODEL IN MULTIGRANULAR LINGUISTIC CONTEXTS *

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The evaluation processes are used for quality inspection, marketing and other fields in industrial companies. This contribution focuses in *sensory evaluation* where the evaluated items are assessed according to the knowledge acquired via human senses by a panel of experts. In these evaluation processes the information provided by the experts implies uncertainty, vagueness and imprecision. The use of Fuzzy Linguistic Approach has provided successful results modeling such a type of information [1]. But in these problems may happen that in the panel each expert has a different degree of knowledge about the evaluated items or indicators. So it seems suitable that each expert can express their preferences in different linguistic term sets based on their knowledge, i.e., the evaluation problem is defined on a multi-granular linguistic framework. Therefore, in this contribution, we shall propose a linguistic sensory evaluation model for multi-granular linguistic contexts based on a decision analysis scheme.

1. Introduction

The evaluation is a complex cognitive process that involves different mechanisms in which it is necessary to define the elements to evaluate, fix the evaluation framework, gather the information and obtain an evaluation assessment by means of an evaluation process. The aim of any evaluation process is to obtain information about the worth of an item (product, service, material, etc.), a complete description of different aspects, indicators, criteria in order to improve it or to compare with other items to know which ones are the best. The information gathered in evaluation processes is usually provided by a group of individuals, called panel of experts, where each expert expresses their opinions about the evaluated items.

The *Sensory Evaluation* [2-4] is an evaluation discipline where the information provided by the panel of experts, is perceived by the human senses of *sight, smell, taste, touch and hearing*. The experts express their opinions about the evaluated object according to their knowledge and their own

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perceptions. This type the information is subjective and difficult to assess quantitatively in a precise way. It is more adequate to express the information, perceived by the human senses in a qualitative way by means of linguistic terms [1]. The Fuzzy Linguistic Approach [5] provides a systematic way to represent linguistic variables in an evaluation process.

It is common that in a panel of experts each one has different knowledge about the evaluated items. So to offer a flexible evaluation framework where they can express their preferences in different linguistic term sets can improve the evaluation results. This contribution proposes an evaluation model based on a decision analysis scheme to deal with sensory evaluation processes defined in multi-granular linguistic frameworks.

This contribution is structured as follows, Section 2 reviews in short several necessary concepts to develop our model. In Section 3 presents our proposal of the sensory evaluation model. Finally, Section 4 points out some conclusions.

2. Preliminaries

Here we review briefly some core concepts about linguistic information and decision analysis.

2.1. *Fuzzy Linguistic Approach*

Usually, we work in a quantitative setting, where the information is expressed by numerical values. However, many aspects of different activities in the real world cannot be assessed in a quantitative form, but rather in a qualitative one, i.e., with vague or imprecise knowledge. In such a case a better approach may be to use linguistic assessments instead of numerical values. The fuzzy linguistic approach [5] represents qualitative aspects as linguistic values by means of linguistic variables.

We have to choose the appropriate linguistic descriptors for the term set and their semantics also an important parameter is the "granularity of uncertainty", i.e., the cardinality of the linguistic term set used to express the information.

One possibility of generating the linguistic term set consists in directly supplying the term set by considering all terms distributed on a scale on which a total order is defined. For example, a set of seven terms S, could be:

$S = \{s_0: None;\ s_1: Very\ Low;\ s_2: Low;\ s_3: Medium;\ s_4: High;\ s_5: Very\ High;\ s_6: Perfect\}$

Usually, it is required that in the linguistic term set there exist:

1. A negation operator: $Neg(s_i) = s_j$ such that $j = g-i$ ($g+1$ is the cardinality).
2. An order: $s_i \leq s_j \iff i \leq j$. So, there exists a minimization and a maximization operator.

The semantics of the terms are given by fuzzy numbers defined in the [0,1] interval, which are described by membership functions. A way to characterize a fuzzy number is to use a representation based on parameters of its membership function [6].

2.2. *The 2-Tuple Linguistic Model*

This model was presented in [7]. The 2-tuple fuzzy linguistic representation model is based on the symbolic method and takes as the base of its representation the concept of Symbolic Translation.

Definition 1. *The Symbolic Translation of a linguistic term* $s_i \in S = \{s_0,...,s_g\}$ *is a numerical value assessed in [-0.5,0.5) that supports the "difference of information" between an amount of information* $\beta \in [0, g]$ *and the closest value in {0,…,g} that indicates the index of the closest linguistic term in S (si), being [0,g] the interval of granularity of S.*

From this concept a linguistic representation model is developed, which represents the linguistic information by means of 2-tuples $(s_i, \alpha_i), s_i \in S$ and $\alpha_i \in [-0.5, 0.5)$. This model defines a set of functions between linguistic 2-tuples and numerical values.

Definition 2. *Let* $S = \{s_0,...,s_g\}$ *be a linguistic term set and* $\beta \in [0, g]$ *a value supporting the result of a symbolic aggregation operation, then the 2-tuple that expresses the equivalent information to* β *is obtained with:*

$$\Delta : [0, g] \rightarrow S \times (-0.5,.0.5)$$

$$\Delta(\beta) = (s_i, \alpha), with \quad \begin{cases} s_i & i = round(\beta) \\ \alpha = \beta - i & \alpha \in [-0.5, 0,5) \end{cases}$$

Being s_i *the closest index label to* β *and* α *is the symbolic translation.*

Proposition 1. *Let* $S = \{s_0,...,s_g\}$ *be a linguistic term set and* (s_i, α_i) *be a linguistic 2-tuple. There is always a* Δ^{-1} *function, such that, from a 2-tuple it returns its equivalent numerical value β Є [0, g].*

Proof. *It is trivial, we consider the following function:*

$$\Delta^{-1} : S \times [-0,5,0.5) \rightarrow [0, g]$$

$$\Delta^{-1}(s_i, \alpha) = i + \alpha = \beta$$

This model has a computational technique to accomplish processes of computing with words based on 2-tuples that was presented in [7].

2.3. *Decision Analysis*

The use of decision analysis approach has been successfully applied to evaluation problems in the literature [8, 9]. The decision analysis allows people to make decisions more consistently. However, decision analysis is not an idealized theory for totally rational beings [10]. In fact, experimental evidences shows that people generally do not process information and make decisions in ways that are consistent with the decision analysis approach. Then, although decision analysis is not always followed by the decision makers it is a suitable approach for evaluation processes.

We shall propose in this contribution an evaluation model based on a decision analysis scheme based on a weighted Multi-Criteria Decision Making method. Such a scheme consists of eight phases:

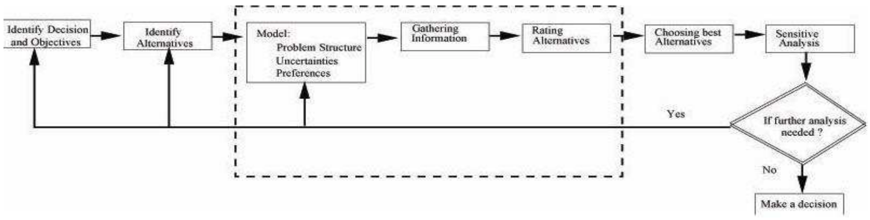

Fig. 1: Decision Analysis Scheme

The application of the decision analysis to an evaluation problem implies only the phases in the dashed rectangle.

3. Multi-granular Linguistic Infor-mation Sensory Evaluation Model

Our aim is to propose a Sensory Evaluation model based on the linguistic decision analysis whose mathematical formalism will be the linguistic 2-tuple model in order to obtain accurate and reliable evaluation results in multi-granular linguistic evaluation frameworks. According to Figure 1 this proposal consists in the following evaluation phases:

- *Identify Evaluated Objects*. This phase is problem-dependent and each problem identifies its objects of interest.
- *Model*: It defines a multi-granular linguistic evaluation framework.
- *Gathering information*: the experts express their sensory knowledge about the objects by means of linguistic assessments.
- *Rating objects*: our proposal uses the 2-tuple computational model to obtain a rate for every object.
- *Evaluation results*: it consists in analyzing the results obtained in the previous phase with the purpose of achieving the evaluation process.

Following subsections present in further detail these phases.

3.1. *Model*

This phase defines the evaluation framework, such that, the problem structure is defined and the linguistic descriptors and semantics that will be used by the experts to provide the information about the sensory features of the evaluated objects are chosen.

First of all, it analyzes the features that will be evaluated. The selection of the linguistic term sets utilized to assess those features will depend on the knowledge and experience of each expert of the panel. Therefore, the granularity of the linguistic term sets are chosen according to the experts knowledge.

3.2. *Gathering information*

The experts provide their knowledge by means of utility vectors that contain a linguistic assessment for each evaluated feature.

$\{e_1,...,e_n\}$, panel of experts. $O=\{o_1,...,o_m\}$, set of evaluated objects

$\{S_1,...,S_n\}$, linguistic term sets. $F=\{f_1,...,f_h\}$, set of evaluated features

e_i provides his/her preferences in S_i by means of an utility vector:

$$U_i = \{u^i_{11},..., u^i_{1h}, u^i_{21},..., u^i_{2h},..., u^i_{m1},..., u^i_{mh}\}$$

where $u^i_{jk} \in S_i$ is the assessment provided to the feature f_k of the object o_j by the expert e_i. Consequently, in the gathering process every e_i will provide her utility vector U_i expressed by linguistic labels in the linguistic term set S_i.

3.3. *Rating objects*

In this phase the linguistic utility vectors provided by the experts will be aggregated in order to obtain a collective preference for each evaluated object. This process is developed according to the following steps:

1. **Making the information uniform**. The multi-granular linguistic information is conducted in an unique expression domain.
2. **Transforming fuzzy sets into 2- tuples**.
3. **Fusion of 2-tuples**. A 2-tuple aggregation operator is used in order to obtain collective values for each evaluated object.

Following, these steps are presented in detail.

3.3.1. *Making the Information Uniform*

The multi-granular linguistic information provided by the panel of experts cannot be directly used in processes of computing with words. Therefore it must be unified in an unique linguistic domain, called Basic Linguistic Term Set (BLTS) noted as S_T. In [11] can be found how to choose S_T.

Once the BLTS has been chosen, the process of making the information uniform transforms the input linguistic labels into fuzzy sets in the BLTS. This process involves the comparison between fuzzy sets representing the semantics of the initial terms assessed in S_i and the fuzzy sets of the linguistic terms of the BLTS. To do so, we shall use *measures of similitude*, in this contribution we shall choose the measure of similitude based on a possibility function.

$$S(A,B) = \max_x \min\{\mu_A(x), \mu_B(x)\},$$

where μ_A and μ_B are the membership functions of the fuzzy sets A and B respectively. Then, to make the information uniform, we use:

Definition 3. [11] *Let* $A=\{l_0,...,l_p\}$ *and* $S_T=\{s_0,...,s_g\}$ *be two linguistic term sets, with,* $g \geq p$. *A multi-granular transformation function,* τ_{AS_T}, *is defined as:*

$$\tau_{AS_T} : A \rightarrow F(S_T)$$
$$\tau_{AS_T}(l_0) = \{(s_k, \alpha_k^0) / k \in \{0, \ldots, g\}\}, \forall l_i \in S$$
$$\alpha_k^0 = \max_x \min\{\mu_{l_o}(x), \mu_{s_k}(x)\}$$

Where $F(S_T)$ *is the set of fuzzy sets defined in* S_T*, and* $\mu_{l_o}(x)$ *and* $\mu_{s_k}(x)$ *are the membership functions of the fuzzy sets associated to* l_0 *and* s_k *respectively.*

The result of τ_{AS_T} for any linguistic value of A is a fuzzy set defined in the BLTS, S_T. We shall denote each $\tau_{S_j S_T}(y^{ij})$ with $y^{ij} \in S_j$, as r^{ij}, that represents each fuzzy set by means of its respective membership degrees, i.e.,

$$r^{ij} = (\alpha_0^{ij}, ..., \alpha_g^{ij})$$

3.3.2. *Transforming Fuzzy Sets into 2-tuples*

So far, we have unified the multi-granular linguistic information by means of fuzzy sets in S_T. To make easy the computations we shall transform each fuzzy set into a linguistic 2-tuple using the function χ that computes a value $\beta \in$ [0,g] that represents a central value of the information in the fuzzy set $\tau_{S_j S_T}(y^{ij})$.

Definition 4. *Let* $\tau_{AS_T}(l_0) = \{(s_0, \alpha_0^0), ..., (s_g, \alpha_g^0)\}$ *be a fuzzy set that represents a linguistic term* $l_0 \in S_j$ *on* S_T*. We shall obtain a numerical value that supports the information of the fuzzy set, assessed in the interval* [0, g] *by means of the following function:*

$$\chi : F(S_T) \rightarrow [0, g]$$
$$\chi(\tau_{S_j S_T}(l_o)) = \frac{\sum_{k=0}^{g} k\alpha_k^o}{\sum_{k=0}^{g} \alpha_k^o} = \beta$$

This value β is easy to transform into a linguistic 2-tuple using the function Δ :

$$\Delta(\chi(\tau_{S_j S_T}(y^{ij}))) = \Delta(\chi(r^{ij})) = (s_k, \alpha)^{ij}$$

3.3.3. *Fusion of 2-tuples*

This phase obtains the result we are looking for, an aggregated value from the multi-granularity linguistic information for each evaluated object.

Here, the input information is modeled by means of linguistic 2-tuples assessed in S_T, $(s_k, \alpha)^{ij}$, and our objective is to aggregate this information. In [7] a wide range of 2-tuple linguistic aggregation operators were presented, therefore, to aggregate the 2-tuples, $(s_k, \alpha)^{ij}$. We shall choose one of the 2-tuple aggregation operators and apply it to combine the 2-tuples, obtaining as a result an aggregated linguistic 2-tuple assessed in S_T. Formally, it can be expressed as:

$$AGOP((s_k, \alpha)^{1j}, ..., (s_k, \alpha)^{nj} = (s_k, \alpha)^j$$

where $AGOP$ is a 2-tuple aggregation operator.

4. Conclusions

The sensory evaluation is an evaluation process in which the information provided by the experts involve in it is acquired via human senses. Therefore this information usually is vague and uncertain. Additionally different experts have different degree of knowledge about the evaluated items.

In this contribution we have presented a sensory evaluation model that offers a multi-granular linguistic evaluation framework to the experts in order to offer a greater flexibility to express their knowledge and obtain better results in the evaluation process. This model will be explored and discussed in detail during the presentation with an application to olive oil sensory evaluation process.

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