A Sensory Evaluation Model with Multiple Linguistic Scales Applied to Affective Test

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Abstract

The evaluation processes are used for quality inspection, marketing and other fields in industrial companies. This contribution focuses on sensory evaluation where the valuations (perceptions) implies uncertainty, vagueness and imprecision. The use of the Fuzzy Linguistic Approach [17] has provided successful results managing such a type of information. In situations where industries need to optimice the acceptation of a product is applied a sensory evaluation test, so-called affective test, which involves a panel of untrained judges. In order to facilitate such evaluation process seems suitable that the judges can express their assessments according their knowledge. In this contribution, we present a sensory evaluation model applied to affective test that manages frameworks with multiple linguistic scales.

Keywords: Sensory Evaluation, affective test, multiple linguistic scales, extended linguistic hierarchies.

1 Introduction

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.), and a complete description of different aspects, indicators, criteria in order to improve or compare, and this way identify which are the best ones.

Here, we focus on *Sensory Evaluation* [6, 12, 15, 16], due to its importance in many sectors related to the consumer products industries (food and beverage, cosmetics, personal care products, fabrics and clothing, pharmaceutical, and so on). The sensory evaluation is an evaluation discipline that was defined as *a scientific discipline used to evoke, measure, analyze and interpret reactions to those characteristics of foods and materials as they are perceived by the senses of sight, smell, taste, touch, and hearing* [14]. The information involved in a sensory evaluation process is always subjective and therefore 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.

On the other hand, the success of any new product on the market depends on the ability of this product to match the consumers needs, tastes and requirements. To increase the success of products and their profits, the food industry must ensure that new products match consumer requirements. The potential acceptability of a new product can be assessed carrying out sensory evaluation tests, affective tests, by means of a panel of untrained judges (ordinary consumers) [16]. The panel

of untrained judges of the product should be diverse in order to guarantee the success of test. Therefore, this set must be composed by consumers of different age, sex, knowledge, etc. However, this diversity implies that the members of the panel might have different degree of knowledge and/or perceptions about the product. Hence, the possibility of offering different scales appropriate for each consumer would improve the evaluation the evaluation results. Due to the fact that sensory evaluation usually deals with qualitative and subjective information the use of the Fuzzy Linguistic Approach [17] has provided successful results modeling such a type of information in evaluation processes [2, 4, 13].

Therefore, the aim of this contribution is to present a sensory evaluation model applied to affective tests with evaluation framework that provides a multiple linguistic scales to the panel of consumers and also provide an accurate computational model to accomplish the processes of computing with words by means of extended linguistic hierarchies [7].

This contribution is structured as follows, section 2 reviews the extended linguistic hierarchies, section 3 presents our proposal for the sensory evaluation model, section 4 presents an example of our model. Finally, section 5 points out some conclusions.

2 Extended Linguistic Hierarchies

We have aforementioned that our proposal for sensory evaluation will deal with multiple linguistic scales in order to make more flexible the evaluation framework to the untrained consumers taking part in affective test.

In the literature there exist different approaches to deal with multiple linguistic scales [3, 8, 10, 11]. In our proposal, we will use the 2-tuple fuzzy linguistic representation model [9] and Extension Linguistic Hierarchy (ELH). The ELH [7] is an extension of hierarchical linguistic that was introduced in [10] in order to improve the precision in the processes of CW in linguistic multi-granular contexts but does not allow to use any linguistic scale. We use the (ELH) because maintains the accuracy and improve the flexibility in the contexts with multiple linguistic scales allowing management of any linguistic scale in such structure.

2.1 Building an Extension Linguistic Hierarchy

An *extension linguistic hierarchy* is a set of linguistic scales, where each scale (level) is a linguistic term set with different granularity from the remaining of levels of the ELH.

Each level belongs to an ELH is denoted as $\mathbf{l}(\mathbf{t}, \mathbf{n}(\mathbf{t}))$, being t the level of the ELH and $n(t)$ the granularity of the linguistic term set of the level t.

We assume levels containing linguistic terms whose membership functions are triangular-shaped, symmetrical and uniformly distributed in $[0, 1]$. In addition, the linguistic term sets have an odd number of elements.

The building of an extended linguistic hierarchy satisfies the following rules, which we call *extended hierarchical rules* [7]:

- *Extended Rule 1:* to include a finite number of the levels, $l(t, n(t))$, with $t = 1, ..., m$ that defines the context with multiple linguistic scales.
- *Extended Rule 2:* to add a new level $l(t', n(t'))$ with $t' = m + 1$ with the following granularity:

  $$n(t') = (LCM(n(1) - 1, ..., n(m) - 1)) + 1$$

  being LCM the *Least Common Multiple* in order to keep all the former modal points of all the previous levels $l(t, n(t))$, $t = 1, ..., m$ within this new level.

Therefore an ELH is the union of the m levels required and the term set $l(t', n(t'))$ that keeps all the former points in order to provide accuracy in the processes of CW.

$$ELH = \bigcup_{t=1}^{t=m+1} (l(t, n(t)))$$

Given a ELH, $S^{n(t)}$ denotes the linguistic term set of ELH corresponding to the level

t of ELH with a granularity of uncertainty of $n(t)$: $S^{n(t)} = \{s_0^{n(t)}, ..., s_{n(t)-1}^{n(t)}\}$.

A graphical example of an ELH is showed in Fig. 1. We can observe that the last level ($t = 3$) contains all the former modal points of the membership functions of each linguistic term, such as we imposed in the building process.

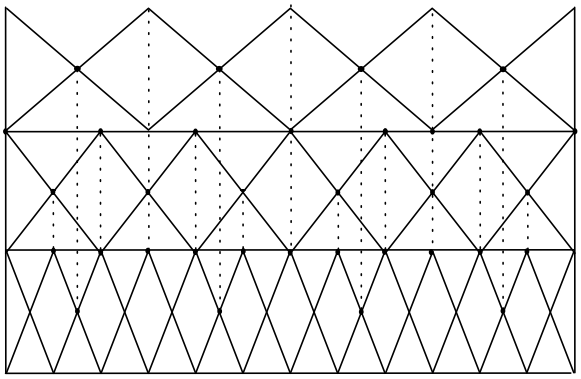

Figure 1: Extended linguistic hierarchy

2.2 CW Processes in ELH

To accomplish CW without loss of information in ELH [7], we will use the linguistic 2-tuple computational model and the transformation functions designed for transforming labels from different levels in the ELH. Then, the computational model is expanded as follows:

First, information is unified in t', the linguistic terms, $s_i^{n(t)}$, must be transformed into the level t' of the ELH.

$$(s_j^{n(t)}, \alpha) \Rightarrow TF_{t'}^{t}(s_j^{n(t)}, \alpha) = (s_k^{n(t')}, \alpha')$$

The 2-tuple computational model is used to make the processes of CW over the linguistic 2-tuples expressed in the term set, $S^{n(t')}$. The results is expressed in linguistic 2-tuples in the level t'.

Once the results have been obtained in the term set, t', by means of linguistic 2-tuples, can be expressed in the initial linguistic term set, t, by means of the transformations:

$$TF_{t}^{t'}(s_f^{n(t')}, \alpha_f) = (s_k^{n(t)}, \alpha)$$

These functions of transformation guarantees the accuracy because the involved levels to keep all the former modal points [10].

3 A Sensory Evaluation Model with Multiple Linguistic Scales Applied to Test Affective

The aim of this contribution is to propose sensory evaluation model for affective test to deal with multiple linguistic scales in order to obtain an evaluation framework where the consumers can express their preferences in different scales depending on their knowledge.

The model is based on the decision analysis scheme [5] that consists of the following phases showed in the Fig. 2.

The following subsections present in detail the main phases of the previous linguistic sensory evaluation model.

3.1 Evaluation Framework

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 consumers to express their information about the sensory features of the evaluated objects are chosen.

The selection of the linguistic term sets utilized to assess those features will depend on the knowledge of the each consumer. Therefore, we propose an evaluation framework with multiple linguistic scales where consumers can express their opinions by means of linguistic labels. Hence, the evaluation framework will be as bellow:

- $C = \{c_1, ..., c_m\}$ set of consumers.
- $X = \{x_1, ..., x_n\}$ set of products to be evaluated sensorially
- $F = \{f_1, ..., f_h\}$ set of sensory features that characterizes each evaluated item x_i
- F_{MS} is formed by m different scales that the consumers will use.

Once the consumers have defined the necessary term sets to express their information,

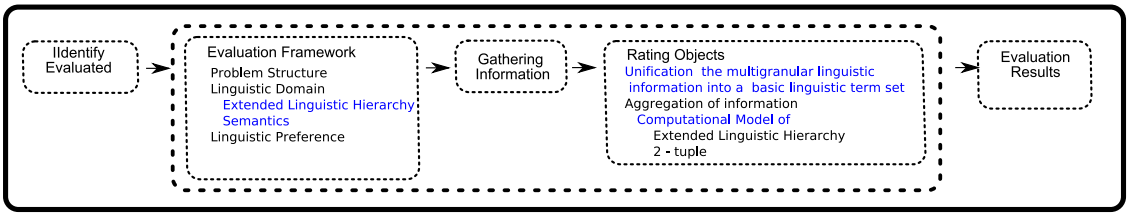

Figure 2: Sensory evaluation model scheme

the ELH that manages the information of the sensory evaluation process is built.

3.2 Gathering Information

After the framework has been defined in order to evaluate the different products, the evaluation process must obtain the knowledge from the consumers.

Due to the fact that, the consumers will provide their knowledge by using utility vectors that contain a linguistic assessment for each evaluated feature. Each consumer, c_i provides his/her preferences in $S_i^{n(t)}$ by means of an utility vector:

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

where $u_{jk}^i \in S_i^{n(t)}$ is the assessment provided to the feature f_k of the product x_j by the consumer c_i.

Consequently, in the gathering process every c_i will provide his/her utility vector U_i expressed by linguistic labels in a linguistic term set in the ELH.

3.3 Rating Objects

The aim of the sensory evaluation process is to obtain information about the worth of an evaluated item, so this phase of the evaluation model computes a global value for each item according to the information gathered in the previous phase.

To compute such a global value, first the information gathered is expressed by means of linguistic 2-tuples using the following remark:

$$u_{jk}^i \Rightarrow (u_{jk}^i, 0).$$

Given that the linguistic information provided by the consumers is expressed in different scales and we cannot compute directly with it, we must be conducted the information into level t', by means of the transformation functions, $TF_{t'}^t$ with t any level in $\{1, ..., m\}$ and $t' = m + 1$.

$$TF_{t'}^t(s_i^{n(t)}, \alpha^{n(t)}) = \Delta\left(\frac{\Delta^{-1}(s_i^{n(t)}, \alpha^{n(t)}) \cdot (n(t') - 1)}{n(t) - 1}\right) \quad (1)$$

Once the information has been conducted in one domain, our model proposes the computing of a global value for an object by means of a multi-step aggregation process [1], the aggregation operators could be the same or different ones depending on each affective test.

- *Computing collective evaluations for each feature.* First, the rating process will compute a collective linguistic 2-tuple, (u_{jk}, α), for each feature, f_k, of the product x_j, using an aggregation operator, AO_1, on the assessments, u_{jk}^i, provided by all the consumers, c_i, and represented in t':

$$(u_{jk}, \alpha) = AO_1((u_{jk}^1, \alpha_1), ..., (u_{jk}^n, \alpha_n))$$

- *Computing a collective evaluation for each object.* The final aim of the rating process is to obtain a global evaluation, (u_j, α), for each evaluated product, x_j according to all the consumers and features that take part in the affective test. To do so, this process will aggregate the collective linguistic 2-tuples for each feature, (u_{jk}, α), using an aggregation operator, AO_2:

$$(u_j, \alpha) = AO_2((u_{j1}, \alpha_1), ..., (u_{jh}, \alpha_h))$$

The aggregation results will be expressed in t', if the problem required it in the initial scales,

Table 1: Utility vectors

	f_1	f_2	f_3	f_4
c_1	s_1^5	s_1^5	s_0^5	s_0^5
c_2	s_1^5	s_1^5	s_0^5	s_0^5
c_3	s_1^7	s_2^7	s_0^7	s_2^7
c_4	s_2^7	s_1^7	s_1^7	s_1^7

our model can be applied the transformation function $TF_t^{t'}$ to the results.

4 Example of Affective Test

In order to understand easily the main phases of the model, we present and solve an example of affective test.

4.1 Evaluation Framework

Let's suppose a sensory evaluation process of four consumers $C = \{c_1, ..., c_4\}$ that will evaluate the intensity of the four features: *Aspect, Smell, Flavor and Texture* that will be noted as $F = \{f_1, ..., f_4\}$ of a sample of coffee $F = \{x_1\}$. The fixed scales have been 5 labels that the consumers c_1 *and* c_2 will use and 7 labels for the consumers c_3 *and* c_4. These scales are building the ELH shown in Fig. 1.

	Scale with 5 labels	
s_0^5	*Like very much*	$(0, 0, .25)$
s_1^5	*Like*	$(0, .25, .5)$
s_2^5	*Neither like nor dislike*	$(.25, .5, .75)$
s_3^5	*Dislike*	$(.5, .75, 1)$
s_4^5	*Dislike very much*	$(.75, 1, 1)$

	Scale with 7 labels	
s_0^7	*Like extremely*	(0, 0, .16)
s_1^7	*Like moderately*	(0, .16, .34)
s_2^7	*Like slightly*	(.16, .34, .5)
s_3^7	*Neither like nor dislike*	(.34, .5, .66)
s_4^7	*Dislike slightly*	(.5, .66, .84)
s_5^7	*Dislike moderately*	(.66, .84, 1)
s_6^7	*Dislike extremely*	(.84, 1, 1)

4.2 Gathering Information

In our qualitative framework, the preferences provided by the consumers are showed in Table 1:

Table 2: Utility vectors in linguistic 2-tuples in $t = 3$

	f_1	f_2	f_3	f_4
c_1	$(s_4^{13}, 0)$	$(s_4^{13}, 0)$	$(s_0^{13}, 0)$	$(s_0^{13}, 0)$
c_2	$(s_4^{13}, 0)$	$(s_4^{13}, 0)$	$(s_0^{13}, 0)$	$(s_0^{13}, 0)$
c_3	$(s_3^{13}, 0)$	$(s_6^{13}, 0)$	$(s_0^{13}, 0)$	$(s_6^{13}, 0)$
c_4	$(s_6^{13}, 0)$	$(s_3^{13}, 0)$	$(s_3^{13}, 0)$	$(s_3^{13}, 0)$

4.3 Rating Objects

The consumers' preferences are transformed into linguistic 2-tuples in the level $t = 3$ by means of the transformation functions, TF_3^1 and TF_3^2, the results of this transformation is showed in Table 2.

We will use the 2-tuple mean operator to aggregate the preferences (AO). The collective values obtained for each feature are:

$$AO((s_4^{13}, 0), (s_4^{13}, 0), (s_3^{13}, 0), (s_6^{13}, 0)) = (s_4^{13}, .25)$$
$$AO((s_4^{13}, 0), (s_4^{13}, 0), (s_6^{13}, 0), (s_3^{13}, 0)) = (s_4^{13}, .25)$$
$$AO((s_0^{13}, 0), (s_0^{13}, 0), (s_0^{13}, 0), (s_3^{13}, 0)) = (s_1^{13}, -.25)$$
$$AO((s_0^{13}, 0), (s_0^{13}, 0), (s_6^{13}, 0), (s_3^{13}, 0)) = (s_2^{13}, .25)$$

The collective value obtained for the sample x_1 is:

$$AO((s_4^{13}, .25), (s_4^{13}, .25), (s_1^{13}, -.25), (s_2^{13}, .25) = (s_3^{13}, -.125))$$

The collective value can be expressed in any linguistic term set of the ELH by means of the transformation functions, TF_1^3 and TF_2^3.

In the scale with 5 labels, the collective value is $(s_1^5, -.04)$ *(Like,-.04)* and in the scale with 7 labels is $(s_1^7, .43)$ (*Like moderately,.43*).

5 Conclusions

The affective test is a type of sensory evaluation test used by the industry to optimice a market product acceptability. In this test, the information provided involves uncertainty because it is acquired via human senses. Usually, this information is vague and uncertain, so a qualitative modeling is quite suitable. Additionally, the affective test is carry out by a set of consumers chosen at random with different knowledge. In this contribution, we have presented a sensory evaluation model applied for

affective test that manages frameworks with multiple linguistic scales the consumers in order to offer a greater flexibility to express the consumers' knowledge and obtain better results in the affective test.

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