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STUDY ON SUBJECTIVE EVALUATION OF PERCEIVED QUALITY OF FLAP MOBILE PHONES AND PREDICTION OF SENSORIAL PROFILE.

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Abstract

Expert opinion is fundamental in any evaluation of perceived quality. However, this can pose some problems for firms. Experts need to be trained, paid and be completely devoted to their task and ideally there must be more than one. All these factors add up to expert advice being very costly for a firm. In order to find a solution to this, we have created a referential for sensorial evaluation from which we can deduce expert responses without calling on their assistance.

Using a previous analysis of perceived quality, where experts took part and gave their opinions, we found some correlations between the sensorial descriptors and the objective descriptors. The methods employed are quite distinctive from each other and this enables us to check the results. The methods employed comprise: Principal Component Analysis, Multiple Factorial Analysis of correlations, Cross Tabulation, classical statistics and finally, we have represented the referential visually using a graph which enables us to observe the correlations clearly.

Following on from this we created a sensorial evaluation referential. This referential is a set of inference rules "IF…THEN…." which enables us to pass from psychoacoustic or biodynamic descriptors to sensorial descriptors and vice versa.

Keywords: Perceived Quality, Subjective evaluation, Objectivated-Subjective and Objective Factors correlation, Psychosensorial rules.

1. Introduction

People perceive the world via their senses. Sight, hearing, touch, smell and taste all play a role in the representation that we build of our environment. As L.Bonaplace explains in his article "The ergonomics of pleasure" [3]:

> *"... The world can be considered as a supplier of stimuli that reach people through sensory channels and that trigger the stimulus and response mechanisms: input, perception, process (cognition), action and output ..."*

In a strongly competitive economic and industrial context, the evaluation of the perceived quality of consumer products is a strategic area of activity responding to implicit and often difficult to express consumer expectations. [7]. In the field of perceived quality evaluation, objective, subjective, and objective-subjectivated evaluation are areas to be mastered.

Sensorial metrology is growing in importance day by day thought it has been used for thirty years in the agri-food and cosmetic sectors and more recently in relation to automobiles and mobile telephones. The objective of sensorial metrology is to define the organoleptic characteristics of products. The results can be exploited in design, in the creation of products that attract the customer and awaken their senses and as such they can have an influence on competitiveness. [1], [12], [2], [13].

Subjective evaluation is a stage that appears to be indispensable in many industrial processes when wanting to judge the perceived quality of an object. When we want to evaluate (judge) the quality of a product, there are often some aspects that cannot be measured in an objective manner (quantifiable and precise) by calibrated measuring instruments. As such, experts are often called upon not only to evaluate the products by giving their opinion, but also by evaluating the trust that they are ready to place in their judgement. For this we use the "expertons" method [11], [20], [14], a method which enables us to interpret the opinion of experts as being an objectivated-subjective piece of data.

A first piece of research [8] concerning mobile telephones enabled us to identify several factors concerning perceived quality. In parallel, we analysed several existing pieces of research on mobile telephones [13], [5], [16], [19]. Following the evaluation and the weighing of these criteria according to their importance and their impact at the moment of purchase, we undertook some research aiming to measure the contribution of each flap-phone to the perception of the quality of mobile telephones possessing a hinged or sliding flap.

In this article, we are going to explain the procedures that we have followed, in order to carry out an evaluation of the perceived quality of mobile flap-telephones.

2. Objective

The objective of this study is to contribute to building a method enabling to visualise the relationship between the factors of perceived quality (factors influencing the act of purchasing), measured by expert judgements (objectivated-subjective data) and objective data (calibrated instruments). In other terms, via these relationships we set out to predict the sensorial profile of a new product by a certain number of combined instrumented measures.

3. Experimentation

3.1 Subjective evaluation. Practical test

The aim of the practical questionnaire was to define a list of descriptors that could be exploited in the translation of the expectations and feeling of the users. It was essential to ask open questions.

3.2 Subjective evaluation. Hedonic test

The objective of the hedonic test is to obtain a subjective evaluation of the preferences of the persons questioned concerning the acceptability of the telephones presented.

3.3 Objectivated-subjective evaluation. Expert test

A test involving expert opinions is one of the most important tests in sensorial analysis but also one of the most delicate to carry out.

Expert opinion is characterised as being "objective", but if we want to be more precise, we can qualify it as being "objectivated-subjective" opinion. This is more correct since, being human beings, they have the right to make errors or to have doubts. We undertook studies in order to objectivate and evaluate expert's uncertainty [14]. Here we will treat expert opinion as being objectivated-subjective.

We called upon 6 experts for our study and established with them the descriptors that objectively define the properties of our flap-telephones. These descriptors are precise (they are not ambiguous), discriminative (the range of marks attributed for each of them is the widest possible), exhaustive (describing the product in an exhaustive manner) and independent (in order to obtain a maximum of information for a minimum of descriptors) [17].

These experts underwent a training based on several copies of the real sensorial test (mock test). This training is an important phase in the training of a group, and must enable the expert to:

a) become familiar with the test vocabulary, in order to have a shared vocabulary with all the other experts (mono-dimensional descriptors) and to define each of the descriptors clearly [2];
b) identify the characteristics that he/she has already seen in the new products;
c) calibrate their evaluations on ranges of known concentrations in order to judge the intensities;
d) Compare his/her perception with that of others [17].

The sensorial questionnaire is made up of three parts: acoustic, manipulation and visual, comprising a total of 13 questions. The average time per test is one hour and a quarter. This duration is relatively short, therefore the experts don't become tired and as a consequence the quality of their answers is not affected.

We refer the reader to the corresponding article [14] giving more information on this test approach and the application of the "expertons theory".

3.4 Psychoacoustic measurements

In classic acoustics, methods exist which enable to measure sound intensity expressed in dB. However these methods reflect physical magnitudes and cannot take into account human factors. This is why psychoacoustics offers parameters supposed to lead to a better classification of sounds. In particular we are concerned by the following criteria [21]: loudness, sharpness, tonality, roughness and sensory pleasantness.

Given the necessity to isolate the sound, we have used an isolating chamber; a mobile telephone and a microphone are placed inside. The person carrying out the test inserts his/her hands into the box and repeats the manipulation of opening and closing the flap several times in order to record the sounds produced for future digital treatment.

3.5 Bio-dynamic measurements

The aim is to measure various criteria during the act of opening and closing the flap: speed, the critical angle (the angle at which the flap opens/closes by itself) and the force required.

The mobile telephone is fixed on a ball and socket joint that enables to modify its inclination angle. This system is itself fixed on rails enabling to move the mobile telephone backwards or forwards on an axis by operating a handle situated at the extremity of the test set-up which is controlled manually.

The forces associated with the opening and closing of the flap are detected by a force sensor. The detection of acceleration is made with an accelerometer which is placed on the flap of the telephone. The speed of opening and closing is calculated from acceleration and time.

The reproducibility of the results is checked by repeating three successive tests for each parameter.

4. Data table

If we add together all the different results of each part (sensorial – table 1-, psycho-acoustic – table 2-, and bio-dynamic –table 3-) we obtain a general profile for each mobile on which we can carry out statistical tests and then draw conclusions.

Table 1: Sensorial profile for mobile H.

Mobile	Hard, clear		Muffled		Vibrating		(…)		Homogeneous	
H	Bi	Bs	Bi	Bs	Bi	Bs	Bi	Bs	Bi	Bs
	0.67	0.67	0.97	1.00	0.28	0.36	(…)	(…)	0.81	0.86

Table 2: Psychoacoustic profile for mobile H

Mobile	Loudness	Sharpness	Tonality	Roughness	Pleasure
H	3.44	1.21	62.17	1.29	0.05
Units	Sone	Acum	Tonie	Asper	Pu

Table 3: Biodynamic profile for mobile H

	Opening			Closure		
Mobile	**Speed**	**Strength**	**Critical Angle**	**Speed**	**Strength**	**Critical Angle**
H	259.615	0.438	71	310.458	0.179	47.5
Units	º/s	N	º	º/s	N	º

Table 4: Classification for mobile H

Mobile (Classification)	Acoustic	Biodynamic	Visual
H	1	1	5

5. Analysis of results

5.1 Hedonic test

The hedonic test carried out with representative consumers of a given target population, will serve to reveal the level of satisfaction generated by each of the descriptors. It will show if the mobile has achieved an acceptable level in the eyes of the consumers and if the descriptors are liked or not.

The results for our study are the following:

Table 5 : Hedonic test results

Position	Biodynamic	Psychoacoustic	Visual
1	H	H, O	J
2	F	R	B
3	J, P	T	F

5.2 Characterisation of mobiles using an analysis of original perceived quality due to correspondences and the hedonic classification

Let us assume that there is a product (new, made by the competitor etc.) that must be analysed. We have made a first analysis of the perceived quality with several mobiles for which we know the sensorial characteristics and which enabled us to obtain the corresponding psychosensorial quantities. Therefore we have the equivalents of the objective and the objectivated-subjective descriptors. This means that to define this new mobile, we must submit it to just a few tests.

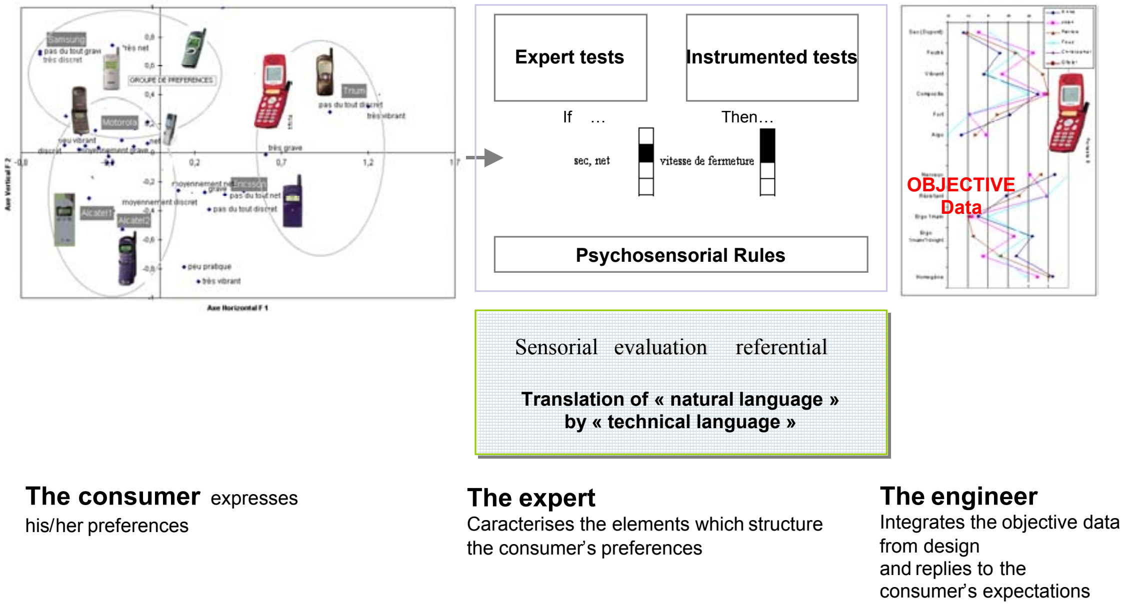


Figure 1: Study of a product in relation to the previous perceived quality analysis

As we have highlighted throughout this article, the reasons for relating the bio-dynamic and the psycho-acoustic data with the sensorial data is precisely to be able to provide an automatic sensorial expertise, without convoking once again the experts for a routine evaluation. The final objective is to be able to repeat the analysis with a new product, whether it be in the process of being developed or whether it comes from the competitive market.

6. Exploitation of results. Extraction of correspondences between descriptors

6.1 Principal Component Analysis (P.C.A.)

One of the most common methods of statistical treatment is PCA (Principal Component Analysis). Its interpretation is based on the representation of the initial data with the aid of clusters in a geometrical space. The objective being to find sub-spaces representing as best as possible the initial cloud. In this way, we can visualise the relationships between the sub-spaces produced and the sub space descriptors, and hence draw conclusions.

Here we show the combination of the most important axes. The figure is formed by axes 1 and 2 that contain more than 75% of the total information.

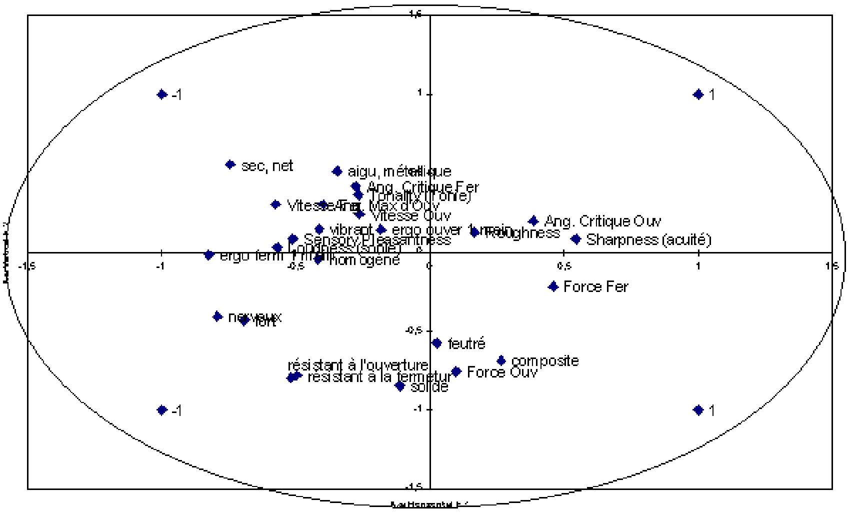


Figure 2 : PCA Axes 1-2. Representation of all the descriptors

The conclusions that we draw from the PCA graphs are the relationships between the descriptors. We represent some of the relationships identified, in the following table:

Table 6: Relationships between the descriptors found via the PCAs

	Loudness	Acuity	(…)	Closure speed
Hard, clear				X
Muffled				
(…)				
Ergonomic closure 1 main	X			X
Homogeneous				

With these relationships and a multiple factorial analysis, we observe the evolution of each relationship.

6.2 Multiple Factorial Analysis of Correspondences MFA

To develop a factorial analysis of correspondences, we have to transform the continuous data into discrete data and regroup it into classes. We have selected four classes that we divide into several value zones: high value (represented by the number 4), moderately high value (number 3), moderately low value (number 2) and low value (number 1).

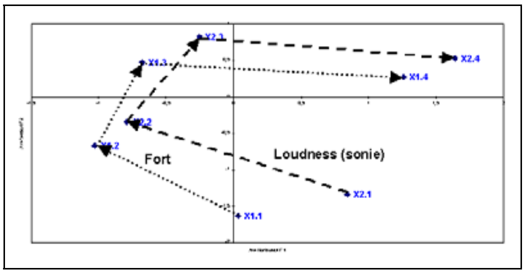
We note that this division is sufficient because it enables us to interpret the results well. If we increase the number of classes this would complicate considerably the calculations to obtain roughly identical results.

The interpretation of the graphs enables us enrich our results. If on the graph, the lines are parallel and oriented in the same direction, we can say that there is a relationship between the descriptors. If the lines are parallel, but oriented in different directions, the relationship is opposite. If on the other hand, we cannot observe any parallelism, then there is not relationship between the descriptors.

Here we present two graphs. In the first, there is a relationship between the descriptors, which is not the case in the second (fig 3).

As we have set out earlier, the results that we obtain consist of correlations between descriptors. These relationships are of the following type [4], [18], [9]:

IF a mobile has sensorial descriptor « x » with a *high value*, **THEN** the value of the pychoacoustic descriptor « y » is *moderately_low*.



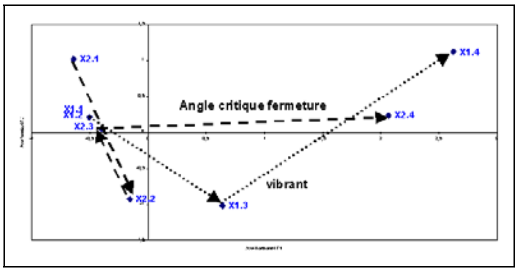


Figure 3 : MFA of the loudness, force and critical angle of flap closure and the vibrational characteristics

As we can note, the relationships are of the type **If** (…) **then** (…). These are conditional relationships and are easy to interpret. In our case, since the correlations can be strong or moderately strong, we have represented the nature of these correlations by colours relating to different values. We can identify four colours:

- Red ®: the relationship is *strong;*
- Pink (P): the relationship is *medium*;
- Yellow (Y): the relationship is *weak*;
- White: no relationship.

A relationship is strong when it occurs in the majority of cases. It is moderate when there is the possibility that it does not occur. And finally, it is weak when we have observed its appearance only a few times.

The correlations obtained form a sensorial evaluation referential. These are the following [4], [18], [6], [9]:

If speed of closure	R / R / (green) / (green)	then hard, clear	– / R / – / –
If speed of closure	– / – / R / –	then hard, clear	– / – / – / R

They evolve in the same direction.

If loudness	– / R / R / –	then ergonomic single-handed closure	– / R / – / –
If loudness	P / P / – / –	then ergonomic single-handed closure	R / – / – / –

These correlations evolve in the same direction

If speed of closure	P / R / – / –	then ergonomic single-handed closure	R / – / – / –
If speed of closure	– / Y / R / Y	then ergonomic single-handed closure	– / R / – / –

These correlations evolve in opposite directions.

Due to the clarity of these correlations, we can predict the sensorial profile of the mobile (at least for certain descriptors) from the psycho-acoustic descriptors and the bio-dynamic descriptors measured during the instrumented tests.

6.3 Cross Tabulation

To carry out the cross tabulation, we start with the same table of classes as in the case of the MFA.

The results obtained are the following:

Table 7: Degree of correspondence in percentages

	Speed of closure				
Hard, clear	**Clos. Speed 1**	**Clos. Speed 2**	**Clos. Speed 3**	**Clos. Speed 4**	**Total**
hard, clear.1	0%	23,08%	0%	0%	*3*
hard, clear.2	7,69%	0%	0%	7,69%	*2*
hard, clear.3	0%	0%	30,77%	23,08%	*7*
hard, clear.4	0%	0%	7,69%	0%	*1*
Total	*1*	*3*	*5*	*4*	*13*

The results are interpreted in the following way. We take as example Table 7. If we look at the line " hard, clear", this refers to the « hard, clear » descriptor at its "moderately high" level. If we follow the numbers of the lines, we retain the percentage of products that have this level. At the end of the row, we find the total (7 in this case) of telephones that are influenced by this descriptor level. We carry on in the same way with the columns. In this way we can observe that in the table 7, the majority of mobiles is represented by a moderately high level for the "hard, clear" descriptor and moderately high level for the closure speed descriptor.

Let us take another example: in the case of a moderately low "hard, clear" and a low "speed of closure," we observe that only 7.69% of the mobiles correspond to this combination. If we look at the totals, we conclude that 7.69% is the equivalent of saying that 1 mobile out of 13 conforms to this relationship.

This system of crossed tabulation enables us to check the relationships that we have found in the previous section (cf. 6.2). So, we need to adopt another manner of checking to see if the conclusions are correct or not. It is essential to proceed with these verifications in a way that does not create correlations between the data that could have no relationship between them.

In this way, if we compare the results obtained with the cross tabulation with those obtained from the MFA, we note that in the great majority of cases, the results are the same. We find the most variations in the cases where the relationships are weak.

Once the results have been compared, we conserve the correlations found in section 6.2 as optimal correlations. We are going to compare them in the next paragraph with the indices of the correlation between descriptors found via the application of classical statistics.

6.4 Classical statistics

We have extracted the relationships between the pairs of descriptors. We have compared each sensorial descriptor with each bio-dynamic and psycho-acoustic descriptor.

The results that we obtain are summarised in an indices correlation table for the pairs of descriptors (cf. Table 8). A correlation index equal to 0 indicates a zero correlation. Whereas an index of 1 indicates a maximum correlation.

Table 8: Correlation index

	hard, clear	**muffled**	**vibrating**	**(…)**	**homogeneous**
Loudness	0,279	-0,039	0,321		0,124
Clos. Force	-0,407	0,159	-0,055		-0,251
Critical Angle Clos.	0,547	-0,243	0,474		0,2
(…)					
Closure Speed	0,583	0,033	0,139		0,075

If we check that the indices found are the highest for the correlations found, this signifies that we have identified a valid and optimal result.

6.5 Objective and objectivated-subjective graph

In order to verify the relationships found, we have drawn a graph where one finds the sensorial, bio-dynamic and psycho-acoustic results (with the intervals). We have as many graphs as we have mobiles. The data in the table must be used in such a way as to be comparable. In this aim, we calculate the percentage that the value of a descriptor represents in relation to the other mobiles. For example, for the loudness, the values are those presented in Table 9.

Table 9: Percentage table for the cartography in Figure 4

	(…)	**H**	**J**	**N**	**O**	**(…)**	**Y**
Loudness		3.44	0.17	1.04	4.27		5.98
Loudness (%)		57.5	2.8	17.4	71.4		100

For the values with are intervals, we must represent the lower limit and the upper limit in the same space corresponding to a precise descriptor. For example, if we look at the graph, for the "vibrating" descriptor, the lower limit is 41.7 and the upper limit is 47.2 (see Figure 4);

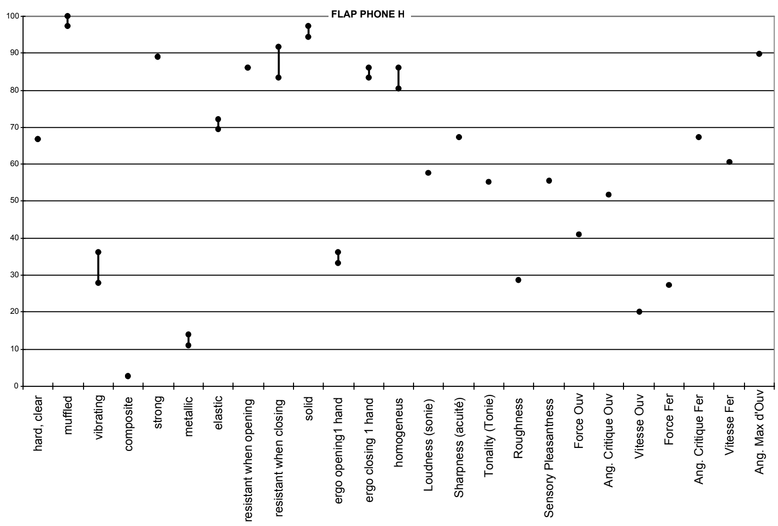


Figure 4: Descriptive profile (objective and objectivated-subjective) for mobile H

We have represented these by two points that are joined vertically, indicating that this is an interval. To verify that the sensorial evaluation referential that we have obtained works in practice, we have tested it with our mobiles and this graph. As can be noted, the relationships are created in an optimal way except for a few cases. If we take the subjectivity of these correlations into account, we can conclude that the results obtained are good.

7. Conclusion

The objective of this article was to predict the sensorial profile, that is, the weighted value of each sensorial descriptor, from the values linked to the psycho-acoustic and bio-dynamic descriptors obtained by instrumented measures. We confirm having obtained relevant results, in the form of a sensorial evaluation referential, allowing to deduce the sensorial profile from objective data.

Let us recall the assumption that the function of experts is to make an evaluation for characteristics that cannot be measured by calibrated instruments.

Experts opinions are fundamental in all evaluations of perceived quality, but they can be backed up and completed, or even replaced in the case of systematic measurements, by a rules based system of psycho-sensorial correspondences.

Using a previous sensorial analysis where experts took part and gave their opinions, we find correlations between the sensorial descriptors and the psycho-acoustic and bio-dynamic data.

The methods employed are distinct between themselves, but they reflect the same result. In this way we have been able to check the results. These methods used are: Principal Component Analysis, Multiple Factorial Analysis and the Cross Tabulation method.

The Principal Component Analysis enabled us to obtain the most significant relationships between descriptors.

Following on from this we confirmed and added detail to these correlations with a Multiple Factorial Analysis of correlations. In this way, we were able to observe the direction of evolution of the descriptors and create the psycho-sensorial referential for sensorial evaluation.

The cross tabulation and percentages table as well as classical statistics enabled us to define the indices of digital correlations (from 0 to 1) between pairs of descriptors.

Finally, we represented the psycho-sensorial referential visually in the form of a graph. This includes all the descriptors. It enables us to observe the correlations clearly and visually.

We knew from the start that we would be faced with one of the most complicated cases of sensorial analysis. However we have succeeded in finding very encouraging results. By our approach, we hope to have made a useful contribution to the field of perceived quality.

8. Perspectives

The next stage consists of the automation of the formalisation of psycho-sensorial rules using a fuzzy algorithm in the data system or fuzzy rule based systems of the type, "if-then" [4], [18], [9]. Establishing membership functions is renowned to be one of the longest processes of fuzzy logic application in order to arrive at genetic algorithms [10], [6]. The approximation by neuro-fuzzy classifiers [15] could also be a very good approach here.

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