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Fuzzy Evaluation of the Thermal Quality of Buildings

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Abstract

This paper presents an application relevant to civil engineering that deals with the classification of the thermal quality of buildings using a fuzzy multiple attribute decision support tool. The aim of the paper is to demonstrate the potential and flexibility of using these type of tools in the civil engineering area. The application selected follows the Portuguese standards for classifying building insulation construction projects.

1. Introduction

This paper describes an application which deals with the classification of the thermal quality of buildings. It uses a multiple attribute fuzzy decision support tool, henceforth denoted by MAF-DSS [6] This MAF-DSS is a general tool capable of solving classification problems which contain imprecise criteria. The purpose is to demonstrate the potential and flexibility of using this type of tool in civil engineering and, more specifically, in classification problems in this area.

The application is based on a crisp expert system developed to evaluate and provide guidance about thermal quality in winter for residential buildings in Portugal [5]. Only the winter season is evaluated because reference values are determined with the number of sunny days in winter.

The main objective of the base model is to classify and propose measures to determine project-quality buildings. Using this application in the MAF-DSS will show: first, the advantages of using a fuzzy tool capable of working with uncertainty; second, the properties and differences of the two available classification types; and third, the extra knowledge obtained about the subject when comparing the crisp and fuzzy results. In order to create the knowledge base in the MAF-DSS all parameters and classifications of the expert system were closely followed, except that criteria were fuzzified. This allows a meaningful comparison of the crisp and fuzzy approaches and emphasizes the gains obtained with the MAF-DSS.

The next sections will discuss, first, the main aspects of the MAF-DSS, second the application of classifying the thermal quality of buildings and finally the conclusions.

2. The Multiple Attribute Fuzzy Decision Support System (MAF-DSS)

The MAF-DSS is a general context-independent system for fuzzy multiple attribute problems. It is based in the decision making in fuzzy environments [4, 8,12] and it also contains a meaning representation language for natural languages queries [10] for supporting the decision-making process.

The main features of the MAF system are: 1. It is interactive and user-friendly in the sense that all dialogue with the user is guided by scroll-bar menus and dialogue-boxes, from the 'construction' of specifications to the manipulation and selection of query-types. 2. It is a flexible system in terms of handling attributes/criteria and objects (sub-attributes), such as the insertion of new objects, attributes, classes, cases and objectives, as well as modifications of their respective values. 3. It incorporates simulation facilities, providing an efficient way for the user to change preferences-weights that enable the tuning of the system and sensitivity analysis. 4. it contains a 'learning ability' since the decision maker can learn about the problem by using the natural language query module and/or the simulation ability. 5. It provides various types of inferencing since the user may employ more than one type of reasoning. Further, it provides the possibility of addressing and solving a large number of different problems.

2.1. The Knowledge Structure

The MAF-DSS components of the knowledge representation kernel are classes, attributes, objects, universes, objectives and cases. Classes represent a set of alternatives of the problem. A criteria is a characteristic or feature common to a collection of alternatives, for example the price of a car. Attributes are elements of criteria that can be either crisp or fuzzy and, if fuzzy, discrete or continuous. E.g. within the criteria price attributes could be cheap, average, expensive. An objective is a relation, used for classification or selection of a class (set of alternatives) and a set of attributes (constraints) of the alternatives. Cases depict instantiations of alternatives and their specific values for each attribute included in the abstract representation of objective. Thus, there exists a one-to-many relation between objective and cases. Examples of the most relevant entities, in FRIL syntax notation [2] are:

Class:

description: list of alternatives

example: ((class cars (volvo, honda, rover))

Criteria:

description: list of attributes per criteria

type: crisp or fuzzy; discrete or continuous

example: ((attribute fuzzy price (cheap, average, expensive)))

Attributes:

description: fuzzy set definitions of attributes

example: ((cheap [$9000: 1 $11000:0]))

The attribute example needs further clarification because it contains the fuzzy set definition in FRIL notation. Lets start by defining what is a fuzzy set [9]. A fuzzy set **A** in the universe **U** is characterized by a membership function $\mu_A(u)$ which associates with each object **u** in **U** a real number in the interval [0, 1] and the value of $\mu_A(u)$ represents the grade of membership of **u** in **A.** In the example, the first number $9000:1 represents the lower limit of the fuzzy set, $9000, and its respective membership value, $\mu=1$. The second number represents the upper limit, $11000 and its respective membership, $\mu=0$. The FRIL language using the two limits constructs the corresponding fuzzy set. This paper uses triangular functions for the definitions of continuous fuzzy sets. The graphical representation of the fuzzy set defined in the above example is depicted in Fig. 1,

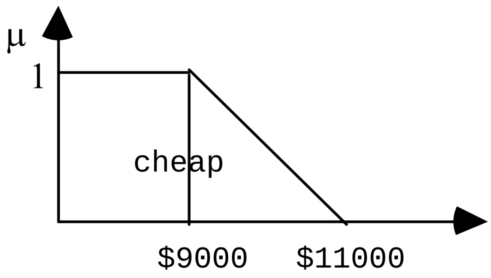

Fig 1. Example of a fuzzy set

After presenting the main entities of the MAF-DSS, a brief introduction to the mathematical normalization of the decision process is needed, to clarify its use for the thermal quality of buildings application.

2.2. The Inference Process

The MAF-DSS follows the general definition for multi-attribute decision processes [4, 7, 8] Let $\mathbf{A_1}$, $\mathbf{A_2}$, ..., $\mathbf{A_m}$ be a set of alternatives to be assessed by criteria $\mathbf{C_1}$, $\mathbf{C_2}$, ...,$\mathbf{C_n}$, which here are called attributes. For each attribute/criteria $\mathbf{C_j}$, we have its membership value per alternative, $\mu_{cj}(A_i)$, which indicates the degree to which any alternative $\mathbf{A_i}$ satisfies that attribute. The overall decision solution for each alternative $\mathbf{A_i}$ becomes an aggregation of the individual attributes/criteria,

$$D(A_i) = \mu_{c1}(A_i) \, O \, \mu_{c2}(A_i) \, O \, .. \, O \, \mu_{cn}(A_i) \qquad ...(1)$$

where the symbol "O' represents an aggregation operator such as the min, max, sum or product. In this paper we use the product and the max because we have two different inference reasoning processes.

The optimal decision **D*** is given by the alternative with the highest membership in $\mathbf{D(A_i)}$,

$$D^* = \max D(A_i). \qquad (2)$$

Henceforth, it should be noted that in this paper criteria are called attributes and "support" refers to the value obtained for the decision solution, $\mathbf{D(A_i)}$.

The MAF-DSS system allows two different forms of aggregating the attributes in the decision process $\mathbf{D(A_i)}$:

1. "Best Match". This process uses the max operator for the aggregation, which implies obtaining the best value from all the assessed attributes for $\mathbf{A_i}$. Formally,

$$D_{bm}(A_i) = \max(\mu_{c1i}, \mu_{c2i}, \ldots, \mu_{cmi}) \qquad (3)$$

and the optimal is given by

$$D^* = \max D_{bm}(A_i). \quad (4)$$

2. "Evidential Logic Rule" [3]. This is an evidential logic reasoning process which allows the weighting of each attribute and uses the sum as the aggregation operator. Formally,

$$D_{evlog}(A_i) = S\left[\sum_j w_j * \mu_{cji}\right] \quad (5)$$

where $\sum w_j = 1$ and $S:[0,1] \times [0,1]$

The weighting coefficient $\mathbf{w_j}$ for attribute $\mathbf{C_j}$ is the relative importance of each attribute in the selection process. **S** is a fuzzy set, acting as a filter to determine the truthfulness of the proposition. For example, if S represents the fuzzy linguistic truth function, *most* [11, 1], then, the final decision support for the evidential logic rule, $\mathbf{D_{evlog}}$, is given by filtering the weighted average value through the function **S** and obtaining the level of truth in *most*.. In this paper we do not use any **S** function, i.e. **S**=1.

To determine the optimal choice $\mathbf{D^*}$, the reasoning with the evidential logic rule allows two choices. The first, corresponding to ranking the alternatives, is denoted "Classification". The second selects the best alternative from the set of alternatives and is denoted "Selection". Thus, for the "Selection" option the optimal decision **D*** is given by,

$$D^* = \max D_{evlog}(A_i) \quad (6)$$

In terms of defining an objective for a problem, this is done interactively in the MAF-DSS, by naming the objective, selecting the class of alternatives and attributes for alternative assessment. During the reasoning process this objective is called either to perform the selection of the best alternative that matches the required criteria, or to perform a weighted classification (evidential logic rule) or a simple best match classification.

Since the application studied in this paper only uses the options described above, no more details about other options of the MAF-DSS are discussed here. Further, the introduction of data for the civil engineering application (another module of the MAF-DSS) is also not detailed here because it is beyond the objective of this paper. However, the next section includes the necessary explanation on how the data is represented and manipulated to achieve the best decision.

3. Thermal Quality of Buildings in Winter

As previously mentioned the application studied in this paper is based on a expert system for determining the thermal quality in winter-time for residential buildings in Portugal [5]. The original expert system is split into two steps: first, classification of the thermal quality of the buildings and, second, providing guidance according to the "grade" in the building construction insulation design. The first step involves three further phases, first the calculation of the parameters, such as thermal quality of cover (K_C) or the thermal quality of pavement (K_P) using different materials. Second, the classification of the parameter value into one of the criteria: *insufficient*, *regular*, *good*, *very good* and *excellent.* Third, the selection of the minimum grade as the final thermal-quality grade of the building, i.e. the support for alternative $\mathbf{A_i}$. The MAF system only deals with step one, classification, and its three phases.

Some factors/criteria limits, related with quality control, are established by the Portuguese official regulations for the determination of thermal-quality of buildings, named RCCT ('Regulamento das Características de Comportamento Térmico dos Edifícios'). When a building does not comply with the regulations, the thermal quality of a building is inferior and fines are applicable. The mandatory regulations (RCCT) are expressed by a reference value, termed NI, which is obtained from the following formula:

$$NI = [((1.3 * K_f * A_f) + (K_h * A_h) + (K_{env} * A_{env}) + (0.34 * P_d * A_p)) (0.024 * GD)] / A_p \quad (7)$$

(kWh/m2 year)

where,

K_f - reference thermal quality loss coefficient for the external vertical walls.
A_f - area of the external vertical walls.
K_h - reference thermal quality loss coefficient for pavement and cover.
A_h - area of the pavement and cover.
K_{env} - reference thermal quality loss coefficient for windows.
A_{env} - area of the windows.
P_d - height from pavement to cover.
A_p - area of pavement.
GD - degrees/day of climatic heat.

The reference value, NI, represents the maximum coefficient of the heat losses per year per square meter for the exterior of a building. The reference tables of the RCCT contain the standard values for three different climatic zones of Portugal and are described in [5]. Hence, in this section they are not described further since second only the calculated values shown are used in the MAF-DSS system.

The RCCT regulations stipulate that the reference value, NI, should be compared with the value NIC, which represents the value obtained for the thermal-quality of a building also considering girders, orientation towards the sun, solar gains etc. NIC is obtained by the formula:

$$NIC = [((f_c * K_f * A_f) + (f_c * K_h * A_h) + (K_{env} * A_{env}) + (0.75 * f_c * K_{int} * A_{int}) + (0.34 * P_d * A_p)) (0.024 * GD) - (A_{env} * G_v * S_v * \_ * ß * f)] / Ap \quad (8)$$

where,

K_f, K_h, K_{env}, A_f, A_h and A_{env} are the same parameters as above but for the building being classified, and,

f_c - factor of concentration of heat losses (e.g. pillars, girders).
K_{int} - thermal quality coefficient for not heated internal spaces .
A_{int} - area of not heated internal spaces .
A_{envs} - area of the windows towards south.
G_v - intensity of the solar radiation on the windows.
S_v - solar factor of the glass.
_ - obstruction factor
ß - factor of the solar gains.
f - orientation factor.

When the result NIC/NI _ 1 the building is considered to comply with the official regulations of the RCCT. An expert system for measuring the thermal quality of a building in winter-time, proposed by Paiva [5], extends the standard NIC/NI classification ratio of the regulations. The proposed model applies interval ratings to other parameters/criteria considered important in terms of thermal quality. The ratings for the thermal quality of the project building are, as previously pointed: *insufficient* (grade 1), *regular* (grade 2), *good* (grade 3), *very good* (grade 4) and *excellent* (grade 5).

The author's claim is that the NIC/NI ratio is not discriminatory enough for determining the quality of building insulation, and therefore it requires further analysis. The proposed new criteria improves the classification and calculation of the thermal quality of a building, providing guidance and control for builders and buyers. Hence, in addition to the NIC/NI ratio, the other criteria parameters used to determine the thermal quality of buildings are: (a) heat loss concentration factor f_c; (b) loss coefficient of the external vertical walls, K_f; (c) thermal quality for the cover, K_c; (d) thermal quality of the pavement, K_p; (e) thermal quality of the windows, K_e. The work of Paiva [5] contains all the tables with the proposed interval range values per climatic zone and for various types of buildings. The MAF-DSS only tests the case of a detached house in the middle climatic zone since the purpose of this exercise is to demonstrate the properties and behaviour of using a fuzzy multiple attribute approach to civil engineering. Table 1 summarizes the range values and respective classifications for each criteria, used to determine the thermal quality in winter-time in the middle climatic zone of a detached house.

As mentioned, the original expert system tests the criteria against three types of buildings, a detached house, a middle story apartment and an upper floor apartment. All three have different construction materials. Furthermore, each building type is tested in three different climatic zones. The MAF system uses the cases with the calculated parameters for, as referred, a detached house in the middle climatic zone. Further, of the original 180 cases only a significant sample of 73 was used. Hence, the cases selected to test in the MAF system, are: 25 with grade *insufficient*; 24 cases with grade *good*; 13 cases with grade *very good*; and 11 with grade *excellent*. No cases with a classification of regular existed in the original and this is the reason why they are not included in the sample. Table 2. transcribes a sample of the selected cases contained in Paiva´s work, page 66.

Houses	**f_c**	**k_f**	**k_c**	**k_p**	**k_e**	**Nic**	**Nic/Ni**
(h1)	1.5	1.4	1.15	1.55	4.2	109.9	1.06
(h12)	1	0.35	0.55	1.55	3.7	54.83	0.53
(h35)	1	0.95	0.35	0.6	4.2	50.06	0.48
(h36)	1	0.95	0.55	0.3	4.2	49.51	0.48
(h37)	1.6	0.75	0.35	0.3	3.7	48.83	0.47
(h40)	1	0.95	0.35	0.3	4.2	45.14	0.44
(h44)	1	0.35	0.35	0.6	4.2	36.83	0.36
(h50)	1.3	0.75	0.55	0.6	3.1	58.57	0.57
(h54)	1	0.95	0.55	0.6	3.1	52.92	0.51
(h71)	1	0.35	0.55	0.3	2.2	31.35	0.3
(h73)	1	0.35	0.35	0.3	2.2	27.13	0.26

Table 2. House attribute values

3.1. Results with the MAF-DSS

In the MAF-DSS approach, criteria are the classifications, *insufficient*, *regular*, *good*, *very good* and *excellent* and the attributes are f_c, K_f, K_c, K_p, K_e, NIC and NIC/NI. Since the objective is to determine the best classification (the minimum classification with value different from zero), the parameters were used as attributes, which are grouped into the respective classifications/criteria. Each column of table 1 presents the values for the attributes (parameters) of each criteria. For instance, criterion *regular* has two attributes the NIC and NIC/NI.

To fuzzify the attributes a triangular distribution with open interval limits, from those available in the MAF system, was used. A deviation of 10% is used to define the slope of the triangles. To illustrate this representation consider the example of criteria *verygood* and its respective attribute definitions, in FRIL language syntax [2].

```
((attribute fuzzy verygood (fc_verygood, nic_verygood, ni_verygood)))

(fc_verygood [1.1:0  1.25:1  1.4:0])

(ni_verygood [0.8:0  0.855:1  0.91:0])

(nic_verygood [45:0   53:1   61:0])
```

The pair $x{:}\mu(x)$ corresponds to the value for the attribute and its membership value. Each fuzzy set is composed of 3 pairs which correspond to the lower limits, medium point and upper limit of the triangular distributions. All the attributes are similarly fuzzified for their respective interval values. Further details about attributes, criteria, classes and objective are described in section 2. The class items are the 73 houses being studied in this paper. The objective is to classify and obtain the minimum classification for each house. Schematically, in FRIL language syntax:

```
((objective isolation_house (houses) (insuf regular good verygood excellent)))

((class houses (h1 h2 h3 h4 h5 h6 h7 h8 h9 h10 h11 h12 h13 h14 h15 h16 h17 h18 h19 h20 h21 h22 h23 h24 h25 h26 h27 h28 h29 h30 h31 h32 h33 h34 h35 h36 h37 h38 h39 h40 h41 h42 h43 h44 h45 h46 h47 h48 h49 h50 h51 h52 h53 h54 h55 h56 h57 h58 h59 h60 h61 h62 h63 h64 h65 h66 h67 h68 h69 h70 h71 h72 h73)))
```

Note: here, insuf means insufficient

The results obtained with the MAF-DSS option "Best Match" (eq. 3) are depicted in Table 3.

Observing the results for house number 31 (h31) it is classified as *good* in terms of thermal quality of its construction. This is the result obtained in the original expert system. However, the MAF system also provides supports for all other criteria which is an advantage of the MAF-DSS because instead of just classifying a house by selecting its lowest grade value, there can be further differentiation. For instance, observe the results of house 30 and 31 (h30 and h31); both will have the same classification with the original expert system while with the MAF-DSS much more information is available. House 31 is certainly better insulated, in terms of thermal quality, since the support for *verygood* is 0.9, while house 30 has a support of 0.

Observing now the results obtained for houses 35 and 40 it might seem that they are identically isolated because they have the same support for criteria *good*, 0.22. However, with the MAF-DSS we can observe that house 35 is better isolated because the *very good* supports are respectively 0.63 and 0.02. Again, for houses 50 and 54, both present the same classification using the original expert system, but in reality house 50 only has a support of 0.67 in *very good* while house 54 has a support of 0.99.

From the results, we can also deduce that if some small adjustment are made on house 44, this could easily jump to classification *excellent*.. House 54 is a good example of how having one or more criteria a little below a higher grade highly penalizes its classification. Numerous other examples could be observed in Table 3. Moreover, the MAF-DSS results could be very useful for a prospective buyer, who using the MAF-DSS classification, can select a house with a better thermal quality.

The "Best Match" option (eq 3) of the MAF-DSS, determines the best match (maximum of all attributes per each criterion) and not a combination of all possible matches, as discussed in section 2. For some problems this reasoning of 'getting the best value from the satisfied attributes' is preferable to 'get the linear combination of all attributes'. The latter reasoning is the inference reasoning process of the evidential logic rule used in the 'Classification' and 'Selection' option of the MAF-DSS (eq 4). For this application both reasoning methods were used, to show their differences and compare and analyze the results with the ones obtained with the original expert system.

The results obtained with option "Classification" (eq 4) from the MAF-DSS, using equally alike preferences (weights, $\mathbf{w_i}$) for the attributes and criteria, are depicted in Table 4. These results are obtained from the linear combined value for the non-empty attributes satisfying each criteria. The results do not show the final support of aggregating all criteria (the support for each alternative, $\mathbf{D(A_i)}$) because it is not crucial for this problem. The aim here is to obtain the minimum classification, for supports different from zero for all grades (criteria). The results are depicted in Table 4.

Analyzing the results of house 30 and 31, in Table 4, they show that the support for classification *good* is smaller for house 31 (0.24) than for house 30 (0.4). The conclusion seems to be that house 30 has a better thermal quality than house 31. However, this is not the case since they have the same support for*excellent* but house 31 has a much better support for *verygood*, 0.30 versus 0 for house 30.

Observing the results for houses 35 and 44 in Table 4, they show that the support for *good* is identical, 0.03. With the original expert system they were both classified as *good* in thermal quality. However, with the MAF-DSS we observe that house 44 has a smaller value than house 35 in the *verygood* criteria but a better value in the *excellent* criteria, i.e. they are not identical in terms of thermal quality . Since the original expert system only deals with crisp information all the information provided by the MAF-DSS about comparison of supports is not available. To have a finer distinguishing classification is an asset of the MAF-DSS approach.

Observing now the results for house 53 we see that it is classified as *verygood*. Since this support is quite high (0.53) we can deduce that some improvements on the parameters involved in the criteria, could boost its classification to *excellent*.. House 53 is another good example of how the MAF-DSS can provide information about houses that are in the frontier from one classification to another.

Another interesting analysis is the case of houses that fail to comply with the RCCN regulations, the ones classified with *insuf*. For instance, looking at the supports for house 14, in Table 4, we see that the classification for *verygood* and *excellent* are significant, but because the house failed in some parameter the final classification is *insuf*. A detailed analysis of the parameters involved might result in recommendations for improvements which can change this situation. Many more examples with similar characteristics as the ones pointed out, can be observed in Table 4.

In conclusion, the MAF-DSS shows good potential for dealing with rating problems perhaps even providing more complete information. The extra information is mainly due to the fuzziness characteristic which can establish fine differences between the grades. For instance, from a bulk of cases with the same classification, such as 'good', the MAF-DSS is able to rank them, displaying degrees inside the main classification. With a traditional approach this is not possible. Furthermore, the availability of all the grades for all attributes (in this case the classifications, *insufficient*, *good*, *verygood* and *excellent*) show that a case with the same support for the minimum classification, could easily be differentiated by using the upper classifications grade supports. In summary, the MAF-DSS proved to be a flexible tool for classification problems.

4. Conclusions

The application tested in this paper, 'The Thermal Quality of Buildings in Winter' was extracted from real cases already tested. The main difference is that it is viewed and addressed as a fuzzy multiple attribute problem. This type of approach seems appropriate to study other classification problems, as demonstrated by the specific application presented.

The results obtained were analyzed and compared with the original crisp results. This shows that the MAF-DSS can be an efficient tool when dealing with vague or uncertain information, thus providing better quality results. The results also show that, even though the MAF-DSS final results had to be obtained manually, the intermediate results provide more information than the original expert system. These intermediate results could be used as a support tool for the decision making process. Instead of having an automatic decision (not always correct), the decision maker could use what he learned from the intermediate results to define preferences (weights of criteria) dictated by his/her judgment.

Summing up, the use a general and flexible fuzzy multiple attribute system, such as the MAF-DSS, in the civil engineering field can improve the quality of results obtained.

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Grades/ Criteria		**Insufficient** grade: 1	**Regular** grade: 2	**Good** grade: 3	**Very good** grade: 4	**Excellent** grade: 5
fc				fc >1.3	1.1<fc_1.3	1 < fc _ 1.1
K's	Kf	Kf > 1.6		1.2<Kf _1.6		Kf _ 1.2
	Kc	Kc > 1		0.85< Kc _1		Kc _ 0.85
	Kp	Kp > 1		0.85< Kp_1		Kp _ 0.85
	Ke	Ke > 4.2		3.4< Ke_4.2		Ke _ 3.4
NIC			NIC>90	60<NIC_90	45<NIC_60	NIC _45
%NI=NIC/NI		NI>1	.95<NI_1	.9 <NI_.95	.8<NI_.9	NI _.8

Table 1. Thermal criteria for insulation quality of buildings

INSUFFICIENT	h10 good (0.22)	h21 insuf (1)	h32 excellent (1)	h48 excellent (1)
h1 insuf (1)	h10 verygood (0.54)	h21 regular (0)	h33 good (0.66)	h49 good (0.67)
h1 regular (1)	h10 excellent (1)	h21 good (0.22)	h33 verygood (0.95)	h49 verygood (0)
h1 good (1)	h11 insuf (1)	h21 verygood (0.54)	h33 excellent (1)	h49 excellent (1)
h1 verygood (0)	h11 regular (0)	h21 excellent (1)	h34 good (1)	
h1 excellent (0)	h11 good (0)	h22 insuf (1)	h34 verygood (0.71)	VERY GOOD:
h2 insuf (1)	h11 verygood (0.73)	h22 regular (0)	h34 excellent (1)	h50 verygood(0.67)
h2 regular (1)	h11 excellent (1)	h22 good (0)	h35 good (0.22)	h50 excellent (1)
h2 good (1)	h12 insuf (1)	h22 verygood (0.34)	h35 verygood (0.63)	h51 verygood (0.73)
h2 verygood (0)	h12 regular (0)	h22 excellent (1)	h35 excellent (1)	h51 excellent (1)
h2 excellent (1)	h12 good (0.66)	h23 insuf (1)	h36 good (0.22)	h52 verygood (0.86)
h3 insuf (1)	h12 verygood (0.8)	h23 regular (0)	h36 verygood (0.56)	h52 excellent (1)
h3 regular (1)	h12 excellent (1)	h23 good (0.67)	h36 excellent (1)	h53 verygood (0.93)
h3 good (1)	h13 insuf (1)	h23 verygood (0.3)	h37 good (1)	h53 excellent (1)
h3 verygood (0)	h13 regular (0)	h23 excellent (1)	h37 verygood (0.5)	h54 verygood(0.99)
h3 excellent (0)	h13 good (0.22)	h24 insuf (1)	h37 excellent (1)	h54 excellent (1)
h4 insuf (1)	h13 verygood (0.9)	h24 regular (0)	h38 good: (0.66)	h55 verygood (0.71)
h4 regular (1)	h13 excellent (1)	h24 good (0)	h38 verygood: (0.4)	h55 excellent (1)
h4 good (1)	h14 insuf (1)	h24 verygood (0.3)	h38 excellent:(1)	h56 verygood (0.67)
h4 verygood (0)	h14 regular (0)	h24 excellent (1)	h39 good (0.67)	h56 excellent (1)
h4 excellent (1)	h14 good (0)	h25 insuf (1)	h39 verygood (0.33)	h57 verygood(0.56)
h5 insuf (1)	h14 verygood (0.96)	h25 regular (0)	h39 excellent (1)	h57 excellent (1)
h5 regular (1)	h14 excellent (1)	h25 good (0)	h40 good (0.22)	h58 verygood (0.67)
h5 good (1)	h15 insuf (1)	h25 verygood (0)	h40 verygood (0.02)	h58 excellent (1)
h5 verygood (0)	h15 regular (0)	h25 excellent (1)	h40 excellent (1)	h59 verygood (0.4)
h5 excellent (1)	h15 good (0.67)		h41 good (0.67)	h59 excellent (1)
h6 insuf (1)	h15 verygood (0.92)		h41 verygood (0)	h60 verygood (0.4)
h6 regular (0)	h15 excellent (1)	GOOD :	h41 excellent (1)	h60 excellent (1)
h6 good (0.08)	h16 insuf (1)	h26 good (1)	h42 good (0.22)	h61 verygood(0.67)
h6 verygood (0)	h16 regular (0)	h26 verygood (0)	h42 verygood (0)	h61 excellent (1)
h6 excellent (1)	h16 good (0.22)	h26 excellent (1)	h42 excellent (1)	h62 verygood (0.01)
h7 insuf (1)	h16 verygood (0.91)	h27 good (1)	h43 good (0.67)	h62 excellent (1)
h7 regular (0)	h16 excellent (1)	h27 verygood (0)	h43 verygood (0)	
h7 good (0.67)	h17 insuf (1)	h27 excellent (1)	h43 excellent (1)	EXCELLENT:
h7 verygood (0.02)	h17 regular (0)	h28 good (1)	h44 good (0.22)	h63 excellent (1)
h7 excellent (1)	h17 good (0)	h28 verygood (0)	h44 verygood (0)	h64 excellent (1)
h8 insuf (1)	h17 verygood (0.85)	h28 excellent (1)	h44 excellent (1)	h65 excellent (1)
h8 regular (0)	h17 excellent (1)	h29 good (1)	h45 good (0.22)	h66 excellent (1)
h8 good (0.059)	h18 insuf (1)	h29 verygood (0)	h45 verygood (0)	h67 excellent (1)
h8 verygood (0.38)	h18 regular (0)	h29 excellent (1)	h45 excellent (1)	h68 excellent (1)
h8 excellent (1)	h18 good (0)	h30 good (1)	h46 good (0.67)	h69 excellent (1)
h9 insuf (1)	h18 verygood (0)	h30 verygood (0)	h46 verygood (0)	h70 excellent (1)
h9 regular (0)	h18 excellent (1)	h30 excellent (1)	h46 excellent (1)	h71 excellent (1)
h9 good (0)	h20 insuf (1)	h31 good (1)	h47 good (0.67)	h72 excellent (1)
h9 verygood (0.4)	h20 regular (0)	h31 verygood (0.9)	h47 verygood (0)	h73 excellent (1)
h9 excellent (1)	h20 good (0)	h31 excellent (1)	h47 excellent (1)	
h10 insuf (1)	h20 verygood (0.54)	h32 good (1)	h48 good (0.22)	
h10 regular (0)	h20 excellent (1)	h32 verygood (0.97)	h48 verygood (0)	

Table 3. Results with option “Best Match”

INSUFFICIENT	h10 good : (0.03)	h20 good: (0)	h32 good:(0.24)	h48 excellent.: (0.86)
h1 insuf: (0.6)	h10 verygood: (0.18)	h20 verygood: (0.18)	h32 verygood.:(0.32)	h49 good :(0.09)
h1 regular:(.77)	h10 excellent: (0.57)	h20 excellent: (0.71)	h32 excellent.: (0.57)	h49 verygood.: (0)
h1 good : (.29)	h11 insuf : (0.2)	h21 insuf: (0.2)	h33 good1: (0.09)	h49 excellent: (0.86)
h1 verygood.: (0)	h11 regular1: (0)	h21 regular: (0)	h33 verygood.:(0.32)	
h1 excellent. : (0 0)	h11 good : (0)	h21 good: (0.03)	h34 good:(0.17)	VERY GOOD:
h2 insuf: (0.6)	h11 verygood: (0.24)	h21 verygood: (0.18)	h34 verygood.:(.0.24)	h50 verygood: (0.32)
h2regular:(0.83)	h11 excellent: (0.71)	h21 excellent: (0.57)	h34 excellent: (0)	h50 excellent: (0.71)
h2 good: (0.26)	h12 insuf : (0.2)	h22 insuf: (0.2)	h35 good: (0.03)	h51 verygood: (0.47)
h2 verygood.: (0)	h12 regular1: (0)	h22 regular: (0 0)	h35 verygood: (0.21)	h51 excellent: (0.71)
h2 excellent.: (0.14)	h12 good : (0.09)	h22 good: (0 0)	h35 excellent: (0.71)	h52 verygood: (0.51)
h3 insuf: (0.56)	h12 verygood: (0.26)	h22 verygood: (0.11)	h36 good: (0.03)	h52 excellent: (0.71)
h3 regular: (0.9)	h12 excellent: (0.57)	h22 excellent: (0.71)	h36 verygood: (0.19)	h53 verygood: (0.53)
h3good : (0.35)	h13 insuf : (0.4)	h23 insuf: (0.2)	h36 excellent: (0.71)	h53 excellent: (0.71)
h3 verygood.: (0)	h13 regular : (0)	h23 regular: (0 0)	h37 good: (0.24)	h54 verygood: (0.33)
h3 excellent.: (0)	h13 good : (0.03)	h23 good: (0.09)	h37 verygood: (0.16)	h54 excellent: (0.86)
h4 insuf: (0.44)	h13 verygood: (0.28)	h23 verygood: (. .1)	h37 excellent: (0.57)	h55 verygood: (0.46)
h4 regular: (0.9)	h13 excellent: (0.57)	h23 excellent: (0.57)	h38 good: (0.09)	h55 excellent: (0.71)
h4 good: (0.26)	h14 insuf : (0.2)	h24 insuf: (0.2)	h38 verygood: (0.13)	h56 verygood: (0.44)
h4 verygood.: (0)	h14 regular : (0)	h24 regular: (0)	h38 excellent: (0.71)	h56 excellent: (0.71)
h4 excellent: (0.14)	h14 good1 : (0)	h24 good: (0)	h39 good: (.0.1)	h57 verygood: (0.19)
h5 insuf : (0.4)	h14 verygood: (0.32)	h24 verygood: (.0 .1)	h39 verygood: (0.11)	h57 excellent: (0.86)
h5 regular: (0.83)	h14 excellent: (0.71)	h24 excellent: (0.71)	h39 excellent: (0.71)	h58 verygood: (0 .39)
h5 good: (0.17)	h15 regular: (0)	h25 insuf: (0.2)	h40 good: (0.03)	h58 excellent: (0.71)
h5 verygood: (0)	h15 good : (0.09)	h25 regular: (0)	h40 verygood: (0.01)	h59 verygood: (0.15)
h5 excellent:(0.14)	h15 verygood: (0.31)	h25 good: (0)	h40 excellent: (0.84)	h59 excellent: (0.86)
h6 insuf : (0.2)	h15excellent: (0.57)	h25 verygood: (0)	h41 good: (0.1)	h60 verygood:(0.12)
h6 regular : (0)	h16 regular: (0)	h25 excellent: (0.86)	h41 verygood: (0)	h60 excellent: (0.86)
h6 good : (0.01)	h16 good: (0.03)		h41 excellent: (0.86)	h61 verygood.: (0.25)
h6 verygood: (0)	h16 verygood.: (0.3)	GOOD:	h42 good: (0.03)	h61 excellent: (0.75)
h6 excellent: (.0.71)	h16 excellent.: (0.57)	h26 good: (0.38)	h42 verygood: (0)	h62 verygood.:(0.01)
h7 insuf1: (0.2)	h17 insuf: (0.2)	h26 verygood: (0)	h42 excellent: (0.86)	h62 excellent.: (0.98)
h7 regular : (0)	h17 regular : (0)	h26 excellent: (0.43)	h43 good: (0.1)	
h7 good : (0.10)	h17 good : (0)	h27 good: (0.36)	h43 excellent: (0.86)	EXCELLENT:
h7verygood:(0.01)	h17verygood.: (0.28)	h27 verygood: (0)	h44 good: (0.03)	h63 excellent.:(1)
h7 excellent : (0.57)	h17 excellent.: (0.71)	h27 excellent :(0.57)	h44 verygood: (0)	h64 excellent: (1)
h8 insuf : (0.2)	h18 insuf: (0.2)	h28 good: (0.46)	h44 excellent: (0.86)	h65 excellent: (1)
h8 regular : (0)	h18 regular: (0)	h28 verygood: (0)	h45 good: (0.03)	h66 excellent: (1)
h8 good: (0.01)	h18 good : (0)	h28 excellent:(0.43)	h45 verygood: (0)	h67 excellent: (1)
h8 verygood : (0.13)	h18 verygood. : (0)	h29 good: (0.42)	h45 excellent: (0.86)	h68 excellent: (1)
h8 excellent: (0.71)	h18 excellent.: (0.71)	h29 verygood: (0)	h46 good : (0.09)	h69 excellent: (1)
h9 insuf1 : (0.2)	h19 insuf: (0.2)	h29 excellent: (0.43)	h46 verygood.: (0)	h70 excellent: (1)
h9 regular1: (0)	h19 regular: (0)	h30 good: (.4)	h46 excellent.: (0.86)	h71 excellent: (1)
h9 good1 : (0)	h19 good: (0.09)	h30 verygood: (0)	h47 good : (0.09)	h72 excellent: (1)
h9 verygood: (.13)	h19 verygood.: (0.23)	h30 excellent:(0.57)	h47 verygood.: (0)	h73 excellent: (1)
h9 excellent : (0.71)	h19 excellent: (0.57)	h31 good :(0.24)	h47 excellent.: (0.86)	
h10 insuf: (0.2)	h20 insuf: (0.2)	h31 verygood.:(0.3)	h48 good : (0.03)	
h10 regular : (0)	h20 regular: (0)	h31 excellent: (0.57)	h48 verygood. : (0)	

Table 4. Results with option “Classification”