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Using Fuzzy sets theory to analyze environmental condition in order to improve animal productivity

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Abstract. Considering the comfort conditions in animal breeding results carried out by a specialist, we carry out another analyze of the same conditions but using the fuzzy sets theory as a mathematical tool. The independent variables considered to analyze the dependent variable, which must reveal the comfort condition, are the air temperature and the relative humidity, both reorganized according to intervals for which there were associated to a kind of classification meaning linguistic terms. After that, a system of rules must be established, which is constructed considering the influence

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of both these variables independent on the variable dependent. As a consequence it is possible to consider distinct scenarios to be mathematically analyzed through of the fuzzy sets theory available at MATLAB 6.5. The comparison between the results obtained previously and the results obtained using this methodology shows approximately the same kind of strategy to the management of the environmental conditions to reach comfort conditions and so reveals the fuzzy sets theory as an alternative to continue researches that are looking for animal productivity improvement.

Key words: *Climatological analyze, comfort conditions, animal productivity, Fuzzy sets theory.*

1 Introduction

An alternative strategy to improve animal productivity, as can be found in the specialized literature, is by the management and/or through by the control of the heat stress, which is a function of the environmental conditions.

Following this strategy, Nienaber et al. (2004) presents a table shown in Figure 1, where it can be identified four categories of the Livestock Weather Safety Index associated with the THI values as a function of the values obtained by the climatological analysis. According to this author, this table was assembled considering the air dry bulb temperature [^0C], Tdb, and the air relative humidity [%] to obtain the dew point temperature [^0C], Tdp, using the following equation:

$$THI = Tdb + 0.36Tdp + 41.2$$

According to the grey color nuance shown in Figure 1, it can be observed the referred four categories: Normal, Alert, Danger and Emergency. These categories reveal another kind of variable, which can be recognized as a linguistic variable once it is natural and not as accurate as those, used from

Relative Humidity, %

Temperature, °C	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
20	63	63	63	64	64	64	64	65	65	65	66	66	66	66	67	67	67	67	68	68
22	64	65	65	66	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72
24	66	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74	75	75
26	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	77	77	78	78	79
28	70	70	71	72	72	73	74	74	75	76	76	77	78	78	79	80	80	81	82	82
30	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
32	73	74	75	76	77	77	78	79	80	81	82	83	84	84	85	86	87	88	89	90
34	75	76	77	78	79	80	81	82	83	84	84	85	86	87	88	89	90	91	92	93
36	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	93	94	95	96	97
38	78	79	81	82	83	84	85	86	88	89	90	91	92	93	95	96	97	98	99	100
40	80	81	82	84	85	86	88	89	90	91	93	94	95	96	98	99	100	101	103	104

Categories of the Livestock Weather Safety Index associated with THI values:
Normal: ≤ 74 Alert: 75-78 Danger: 79-83 Emergency: ≥ 84

Figure 1: Temperature-Humidity Index Values

human bean. So, according to Amendola et al. (2004b), this is the kind of conditions and variable adequate to be analyzed through the fuzzy sets theory. The fuzzy sets theory has been reached several application areas. One of these areas is associated to the fuzzy control, used to the automation of process, since domestic tasks till to complex industrial process (Klir e Yuan, 1995). According the literature, the pioneer fuzzy control application is due to **?**, whose theoretical support can be found in some papers of Zadeh (1965). At the "Faculdade de Engenharia Agrícola - FEAGRI-UNICAMP", the use of fuzzy sets theory could be recognized as an adequate mathematical tool to be used in researches involving animal breeding, just after several events scientific (Amendola, 2004). A resulting pioneer paper of Amendola et al. (2004a) shows the use of this methodology to simulate comfort conditions in broilers production. The suitable results of this work were taken as an incentive to the development of similar projects, as those found in Moura et al. (2004), performed also to broilers; and in Queiroz et al. (2004) to swine; as well to several projects that are still in development. These considerations justify the objective of this paper.

2 Objectives

The aim of this research is to show how the use of the fuzzy sets theory is adequate as an alternative mathematical tool to analyze environmental conditions as able as to suggest comfort conditions in animal breeding process.

3 Material and methods

First of all, according to Amendola et al. (2004a), it is necessary to define a subdivision of the information shown in Figure 1, which must be performed through linguistic terms to construct an inference fuzzy system. This requires a rule system establishment, which must be able to describe the relations between the independent variables and the dependent variables. In this work the inference method used is according to the Mamdani method and the change from fuzzy results to numerical values is obtained by the gravity center method; membership functions must also be selected. All these concepts theoretical can be found in Pedricz e Gomide (1998). The fuzzy analyze is carried out using the scientific computational environment MATLAB 6.5. (Amendola et al., 2004b).

4 Results

The referred subdivision of Figure 1, performed to the temperature variable T belonging to the interval $[20, 40]$, is shown in Table 1, and to the relative humidity, RH belonging to the interval $[0, 100]$, is shown Table 1. By the other hand, in Table 3 it is shown the division to the THI variable exactly as it appears in Nienaber et al. (2004).

The membership functions considered as convenient to represent the independent variables T and RH, as shown in Tables 1 and 2 respectively,

Table 1: Subdivision to the T variable and the associated linguistics terms

INTERVAL	TERM
$[20, 23]$	T_1
$[22, 25]$	T_2
$[24, 27]$	T_3
$[26, 29]$	T_4
$[28, 31]$	T_5
$[30, 33]$	T_6
$[32, 35]$	T_7
$[34, 37]$	T_8
$[36, 39]$	T_9
$[38, 40]$	T_{10}

Table 2: Subdivision to the RH variable and the associated linguistics terms

INTERVAL	TERM
$[0, 6]$	U_1
$[5, 11]$	U_2
$[10, 16]$	U_3
$[15, 21]$	U_4
$[20, 26]$	U_5
$[25, 36]$	U_6
$[35, 51]$	U_7
$[50, 56]$	U_8
$[55, 66]$	U_9
$[65, 71]$	U_{10}
$[70, 86]$	U_{11}
$[85, 100]$	U_{12}

Table 3: Subdivision to the THI variable and the associated linguistics terms

INTERVAL	TERM
$[0, 74]$	N (Normal)
$[75, 78]$	A (Alert)
$[79, 83]$	P (Danger)
$[84, 104]$	E (Emergency)

are triangular, which were subject to some kind of fit to avoid superposition. These functions are shown in Figures 2 and 3 respectively.

By the other hand the membership functions considered convenient as to represent the dependent variable THI, as shown in Table 3, are trapezoidal. These functions are shown in Figure 4.

In Table 4 it is shown the rules system obtained from the all 120 composition of the variables. The elements of this Table, $THI_{i,j}$, must be inter-

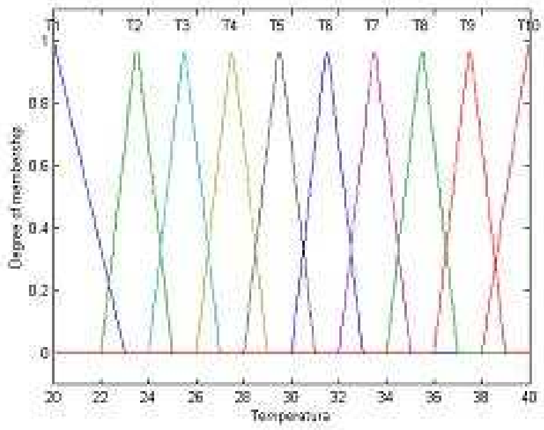

Figure 2: Membership functions to T variable according to Table 1

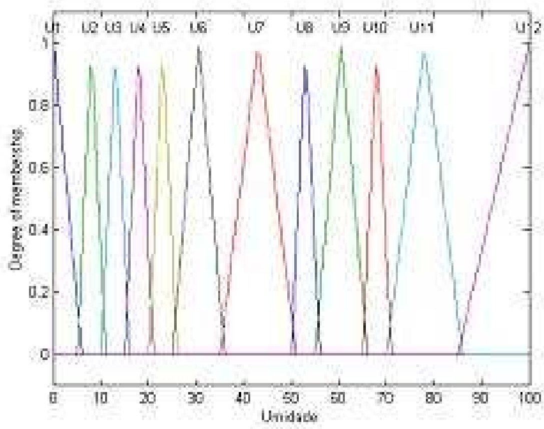

Figure 3: Membership functions to RU variable according to Table 2

preted as $THI(T_i, RH_j)$. For example, $THI_{6,5} = THI(T_6, RH_5)$, represents the Alert condition by the rule:

"**If** T is T_6 **and** RH is RH_5 **then** THI is Alert".

Figure 5 shows the 3D surface generated as a function of the fuzzy sets theory, which summarizes the rules system according to Table 4. Finally, in Figure 6 it is shown the results obtained from the fuzzy methodology.

Table 4: Subdivision to the THI variable and the associated linguistics terms

	RH_1	RH_2	RH_3	RH_4	RH_5	RH_6	RH_7	RH_8	RH_9	RH_{10}	RH_{11}	RH_{12}
T_1	N	N	N	N	N	N	N	N	N	N	N	N
T_2	N	N	N	N	N	N	N	N	N	N	N	A
T_3	N	N	N	N	N	N	N	N	A	A	A	A
T_4	N	N	N	N	N	N	A	A	A	P	P	P
T_5	N	N	N	N	A	A	A	P	P	P	P	E
T_6	N	N	A	A	A	A	P	P	P	E	E	E
T_7	A	A	A	A	A	P	P	E	E	E	E	E
T_8	A	A	A	P	P	P	E	E	E	E	E	E
T_9	A	P	P	P	P	E	E	E	E	E	E	E
T_{10}	P	P	P	P	E	E	E	E	E	E	E	E

In this figure the following colors are in correspondence with the categories established previously: green - Normal, yellow - Alert, blue - Danger and red -Emergency.

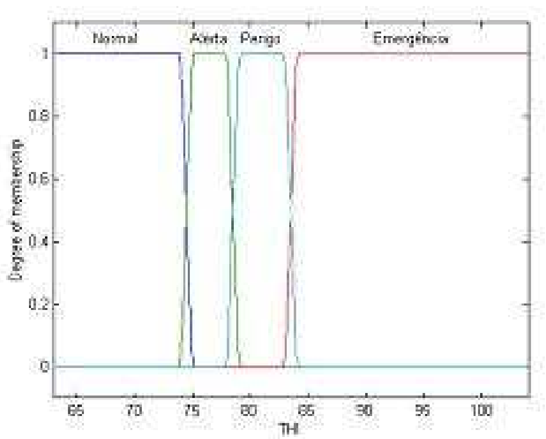

Figure 4: Membership functions to T variable according to Table 1

The associated colors shown in Figure 6 obtained as a function of the fuzzy sets theory and the categories original shown in Figure 1 are in agree-

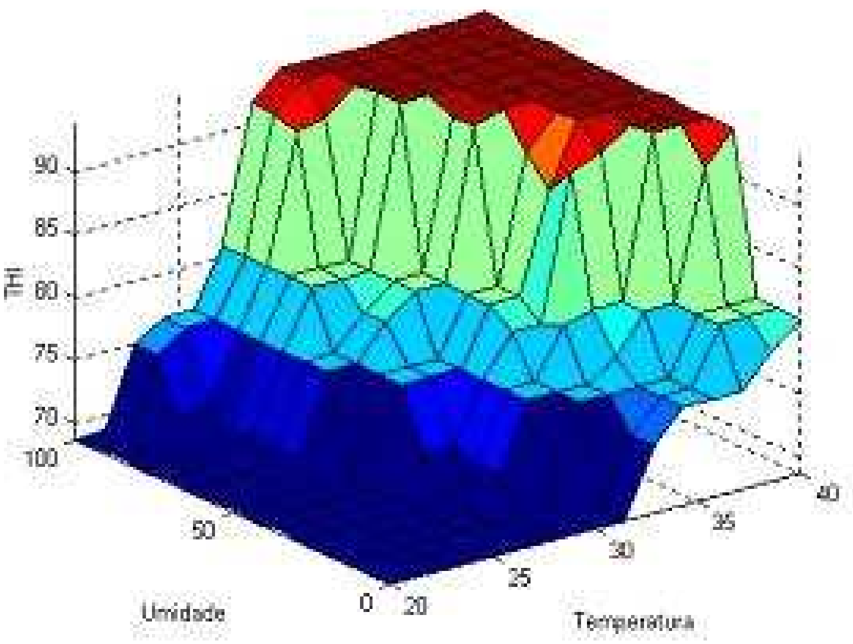

Figure 5: Membership functions to *RU* variable according to Table 2

	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
20	68.9	68.8	68.8	68.8	68.8	68.7	68.9	68.7	68.7	68.9	68.8	68.7	68.9	68.8	68.7	68.7	68.9	68.8	68.7	68.6
22	68.9	68.8	68.8	68.8	68.8	68.7	68.9	68.8	68.8	68.9	68.8	68.8	68.9	68.8	68.8	68.8	68.9	68.8	68.8	68.8
24	68.9	68.8	68.8	68.8	68.8	68.7	68.9	68.7	68.7	68.9	68.8	68.7	68.9	68.8	68.7	68.7	68.9	[illegible]	[illegible]	[illegible]
26	68.9	68.8	68.8	68.8	68.8	68.7	68.9	68.7	68.7	68.9	68.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
28	68.9	68.8	68.8	68.8	68.8	68.7	68.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81.0	81.0	81.0	81.0	81.0	81.0
30	68.9	68.8	68.8	68.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81.0	81.0	81.0	81.0	81.0	81.0	81.0	93.7	93.8	93.8
32	68.9	68.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81.0	81.0	81.0	81.0	81.0	81.0	93.7	93.7	93.8	93.6	93.7	93.8	93.8
34	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	81.0	81.0	81.0	81.0	81.0	93.7	93.8	93.6	93.7	93.7	93.8	93.6	93.7	93.8	93.8
36	[illegible]	[illegible]	[illegible]	81.0	81.0	81.0	81.0	93.7	93.8	93.6	93.7	93.8	93.6	93.7	93.7	93.8	93.6	93.7	93.8	93.8
38	[illegible]	81.0	81.0	81.0	81.0	93.8	93.6	93.7	93.8	93.6	93.7	93.8	93.6	93.7	93.7	93.8	93.6	93.7	93.8	93.8
40	81.0	81.0	81.0	81.0	93.7	93.8	93.6	93.7	93.8	93.6	93.7	93.8	93.6	93.7	93.7	93.8	93.6	93.7	93.8	93.8

Figure 6: Membership functions to *RU* variable according to Table 2

ment but from the exact values. Using this mathematical tool it is possible to obtain results to the dependent variable values as a function of several compositions of the independent variables values in an easy way (it is enough to move and push the cursor in the selected values) to give some kind of decision support to the animal producer as there are shown in the following examples. Selecting specific values of $T = 30^0C$ and $RH = 75\%$ the resulting THI value as it is shown in Figure 7, is $THI = 81$, meaning the Danger condition. This result suggests that one of these selected values must be changed to reach better condition. So, for the same RH value and another selection of T value, $T = 22^0C$, for example, the resulting THI value is $THI = 68.8$, which reveals a Normal and so better category, while if $T = 26^0C$ the THI value is $THI = 76.5$, which reveals the Alert category. Furthermore, for a fixed RH value $RH = 75\%$, it can be concluded that the best THI value occurs for $T = 20^0C$, which is $THI = 68.7$.

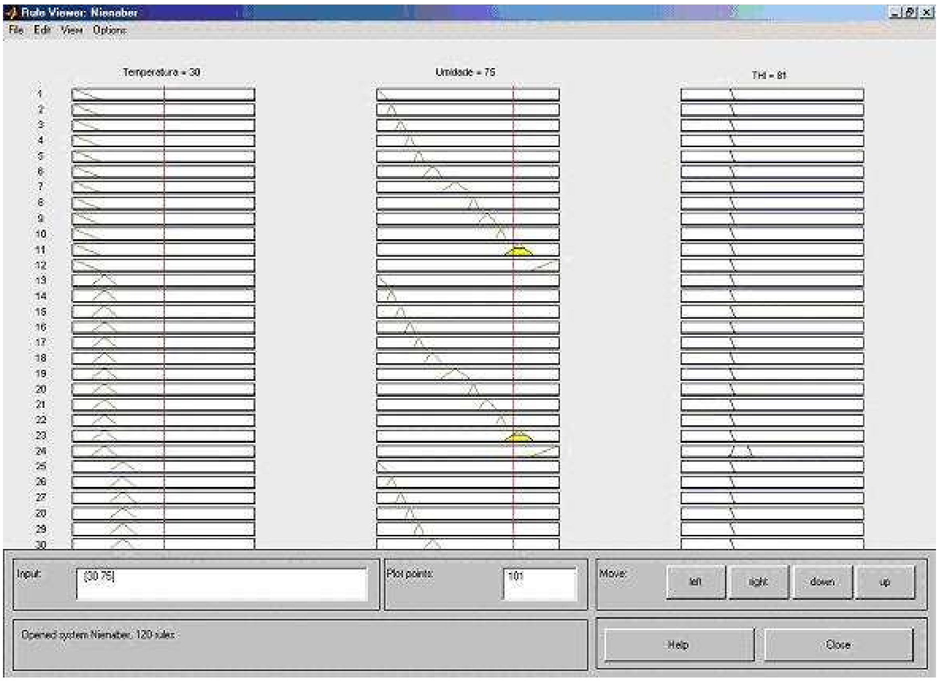

Figure 7: Membership functions to RU variable according to Table 2

5 Conclusions

The result presented in this research shows a good agreement with the original research, and for that confirm the fuzzy sets theory, carried out at the MATLAB 6.5 toolbox, as an adequate tool to continue researches that are looking for animal productivity improvement. As an example we could conclude that for a fixed value of HR, $HR = 75\%$, the best condition of $THI = 68.7$ is reached to the temperature $T = 20^0C$.

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