SISTEMA EXPERTO PARA TOMAR DECISIONES BASADO EN LÓGICA DIFUSA Y PROCESO ANALITICO JERARQUICO ANTE METEOROLOGÍA ADVERSA

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Received: 17/nov/2014 - Accepted: 6/mar/2015 - DOI: http://dx.doi.org/10.6036/7469

EXPERT SYSTEM FOR DECISION- MAKING BASED ON FUZZY LOGIC AND ANALYTIC HIERARCHY PROCESS TO ADVERSE WEATHER

ABSTRACT:

The volume of information used in the Emergency Coordination Center (1-1-2 CECOES), which depends on the Canary Government, during and after any adverse weather phenomenon (FMA in Spanish) is now significantly greater than before, The amount of bulletins warnings and forecasts about FMA sent by the Meteorological Agency (AEMET), and received at the 1-1-2 CECOES, is really considerable. The information should be treated as soon as possible in order to generate the corresponding pre-alerts and notifications, as well as public notices to the citizens

The rule-based expert systems can overcome the human capacity, for example, when required to analyze a large volume of data in a limited period of time, as in the emergency services.

Moreover, Fuzzy Logic is an artificial intelligence methodology that is effective when dealing with vagueness or ambiguity, erroneous or absence of information, something that the emergency services are used to: for example, "It rains a lot", "the storm is far away", " it is windy" and "we have low temperatures" , are typical responses given by some callers when they alert 1-1-2.

Finally, Weather Forecasts usually work with imprecise concepts such as: possibility, (when the probability that a weather phenomenon occurs is between 10 and 40%) and probability, (when between 40 and 70%).

We have primarily developed an expert helping-system for decision-making based on an inference engine implemented with Fuzzy Logic in CECOES 1-1-2. This system is able to provide clear answers at the inaccuracy or lack of information, and if trained with real cases, it can improve human behaviour giving a quick and effective response.

Keywords: CECOES 1-1-2, Adverse Weather Phenomena, Expert System, Artificial Intelligence, Fuzzy Logic, Analytic Hierarchy Process (AHP).

RESUMEN:

La información que se maneja en el Centro Coordinador de Emergencias y Seguridad 1-1-2 del Gobierno de Canarias (CECOES 1-1-2), es algo más que significativa antes, durante y después de cualquier Fenómeno Meteorológico Adverso (FMA). El total de boletines de avisos y predicciones de FMA enviados por la Agencia Estatal de Meteorología (AEMET) y recibidos en el CECOES 1-1-2, en cualquier FMA, son considerables. La información debe ser tratada en el menor tiempo posible, con el fin de generar las prealertas y alertas correspondientes, a la vez que los avisos a la población.

Los Sistemas Expertos basados en reglas pueden superar las capacidades humanas, por ejemplo, cuando se requiere analizar un gran volumen de datos en un corto espacio de tiempo, como ocurre en los **servicios de emergencias.**

Por otro lado, la Lógica Difusa es una metodología del área de Inteligencia Artificial que es eficaz cuando se trabaja con imprecisión o ambigüedad, datos erróneos o ausencia de estos, algo a lo que los servicios de emergencias están acostumbrados. "Llueve mucho", "lejos", "hace mucho viento" y "poco calor" son respuestas típicas dadas por los alertantes cuando llaman al 1-1-2.

Por último, en meteorología se trabaja con conceptos imprecisos como posibilidad (cuando la probabilidad que ocurra un fenómeno meteorológico está entre el 10% y 40%) y probabilidad (cuando está entre el 40% y 70%).

Ante todo esto se ha desarrollado un sistema experto de ayuda en la toma de decisiones basado en un motor de inferencia implementado con Lógica Difusa para el CECOES 1-1-2, capaz de dar respuestas concretas ante la imprecisión o carencia de datos, que entrenándolo con casos reales es capaz de mejorar al comportamiento humano, dando una respuesta más rápida y eficaz.

Palabras clave: CECOES 1-1-2, Fenómeno Meteorológico Adverso, Sistema Experto, Inteligencia Artificial, Lógica Difusa, Proceso Analítico Jerárquico (AHP).

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1.- INTRODUCTION

The Autonomous Communities in Spain treat the adverse weather phenomena (FMA in Spanish) according to the specificities of its Civil Protection Plans (instruments used to respond to emergencies) and, except for those with own agency for weather prediction (Basque Weather Agency), all communities work with the information provided by the AEMET and sets of experts. This causes that all address the FMA with many similarities and problems that arise with multiple matches.

For more than a decade, decision- making in the Canary Islands when FMA occurs has followed the following phases:

1. The information provided by the AEMET when FMA is detected, is received at the CECOES 1-1-2 that immediately informs the Directorate General of Security and Emergency of the Canary Government (DGSE), as the competent body in the statements of pre-alert, alert or highest alert.
2. Based on the analysis of the information received, and applying the Specific Emergency Plan for Risks in the Canary Islands for adverse weather phenomenon (PEFMA) [1], the DGSE declares the pre-alert, alert or highest alert. When processing the information many aspects influence those declarations: the amount of information received, how it has been transmitted through different channels, whether it has been influenced in the process, previous experience of decision makers, the time available to make the decision, etc.
3. The declaration is communicated to CECOES 1-1-2, that immediately communicates this information to administrations, agencies, operational services and companies involved in the operation of PEFMA, in addition to public warnings, if necessary. When additional information or actual data is received, being the FMA in progress, the declaration can be changed, and the process is repeated from Step 1.

The problems that may arise are:

1. The process is influenced by the team of experts involved in decision-making, who are not always the same, as it is a service that operates 24 hours a day, 365 days a year, and so the staff changes according to shifts of work.
2. We work with vagueness, ambiguity, erroneous data or absence of these and expressions of human beings. Furthermore, in meteorology, we work with vague concepts and weather predictions are made using mathematical models that are not always fulfilled in reality. Moreover, the models used do not take into account the uniqueness of the geography of the Canary Islands, which are known as local effects, but nevertheless, they are in the knowledge of experts.
3. Much information is handled, and multiple decisions that affect the lives and property of the people are made in a limited time. The information should be acted upon as soon as possible to generate the pre-alerts, alerts and highest alerts as well as the notifications and the public warnings.

2.- MATERIALS AND METHODS

2.1. EXPERT SYSTEM FOR DECISION- MAKING BASED ON FUZZY LOGIC AND AHP

2.1.1. Introduction

The solutions to problems are given by:

1. Selecting a set of experts (see 2.2.1), specialists in security and emergencies with a high degree of knowledge in the PEFMA and FMA. To select them the "coefficient Competition Expert" or "coefficient K" is applied.” [12] [13].
2. Using the AHP method, proposed by Saaty [3] [4], to collect the knowledge of experts giving consistency, at the same time, to judgements based on mathematical support. A knowledge base is generated and prevents the decision losing objectivity because it may be influenced by the joint team of experts who are on duty. Also, you can introduce new knowledge and prevent it from disappearing when these experts retire or stop working in the sector. Finally, AHP is near a Fuzzy language, making it ideal for working with Fuzzy Logic.
3. Using Fuzzy Logic to work with the vagueness or ambiguity, erroneous data or absence of these, and be able to understand and work with the expressions of humans (see 2.1.3). We build membership functions to evaluate

possible alternatives at all times (pre-alert statements, alerts or highest alerts). The degree of membership to a certain function will be used by the system to propose the ideal alternative.

4. To vary the traditional methodology Fuzzy AHP [11] to simplify calculations with fuzzy sets and apply AHP to make them fuzzy afterwards.
5. To manage the large amount of information in a short time by automating the entire process through a rule-based expert system [5], in which, the knowledge base has been generated by AHP and the inference engine is based on Fuzzy Logic [6]

2.1.2. Multicriteria Decision Methods (AHP)

To make efficient decisions two things are needed: the experience of experts and relevant and verified information that reflects reality.

Decision problems where alternatives are a finite number of values, are studied by the **Methods of Analysis Multicriteria as AHP [3] [4**], based on obtaining weights of importance criteria, sub-criteria and alternatives by comparing peer. The deciders are "value judgments" based on the numerical scale of Saaty (from 1 to 9). The method checks the consistency of the judgments.

AHP decomposes the problem as a hierarchy, and generates local and global priorities of the different elements.

2.1.3. Fuzzy Logic

Fuzzy Logic [7] [8] [9] works with fuzzy sets, which are characterized by a membership function that attach a value to each element in the range [0 1], which determines the degree of belonging to the set.

A fuzzy set is associated with a linguistic value, defined by a word, tag or adjective, which fits with the expressions of human beings.

The granularity of uncertainty [10] is the level of distinction between levels of uncertainty, so that it can properly represent the distinction you want.

2.2. EXPERT SYSTEM FOR DECISION –MAKING BASED ON FUZZY LOGIC AND AHP TO ADVERSE WEATHER PHENOMENA FOR CECOES 1-1-2

2.2.1. Selection of experts

To make the panel of experts we use the method described by Garcia and Fernandez [12] and Cabero [13], called "coefficient K". The coefficient K is obtained through:

$$\mathrm{K} = \frac{(\mathrm{Kc} + \mathrm{Ka})}{2}$$

Kc: expert knowledge coefficient about the problem

Ac: numerical value from the expert himself self-assessment of knowledge

$$\mathrm{Kc} = \frac{\mathrm{Ac}}{10}$$

Ka: argument of the criteria coefficient for each expert.

$$\mathrm{Ka} = \sum_{1}^{i} \mathrm{Ci}$$

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Ci is the value corresponding to (high, medium and low) level contributed by each expert for each source of knowledge. According to Garcia and Fernandez [12] the skill or competition coefficient is evaluated from:

- Si $0.8 \leq K \leq 1.0$ the skill coefficient is high.
- Si $0.5 \leq K \leq 0.8$ the skill coefficient is medium.
- Si $K \leq 0.5$ the skill coefficient is low.

	Experience in security and emergency.			Specific Experience about the problem.			Sense of responsibility and proactivity.			Ability to Analyze and team working skills			Own criteria, common sense and intuition			General qualifications				
Kc	High	Med	Low	High	Med	Low	High	Med	Low	High	Med	Low	High	Med	Low	High	Med	Low	Ka	K
	0,40	0,32	0,20	0,20	0,16	0,10	0,20	0,16	0,10	0,05	0,04	0,025	0,05	0,04	0,025	0,10	0,08	0,05		
0,90	0,40			0,20			0,20			0,05			0,05			0,10			1,00	0,95
0,70		0,32			0,16			0,16		0,05				0,04			0,08		0,81	0,75
0,90	0,40			0,20			0,20			0,05				0,04		0,10			0,99	0,94
0,70		0,32			0,16			0,16		0,05			0,05				0,08		0,82	0,76
0,70		0,32			0,16			0,16			0,04			0,04			0,08		0,80	0,75
0,80		0,32			0,16		0,20			0,05			0,05				0,08		0,86	0,83
0,90	0,40			0,20				0,16		0,05			0,05			0,10			0,96	0,93

Table1. Calculation "Expert skill coefficient"

Only 4 experts have a high skill coefficient, we will work with them for the extraction of knowledge through AHP.

2.2.2. Expert system for decision-making based on fuzzy logic and AHP to adverse weather phenomena for CECOES 1-1-2

Once the experts have been selected and relying on Fig. 1 the overview of the system is:

- Data entry, all relative to FMA are fuzzed to be treated by the kernel. The fuzzification makes truth values become fuzzy values. The input variables, the ranges of variation and fuzzy sets associated with membership functions are defined in 2.2.3 and 2.2.4.4.
- In the system kernel, where the knowledge base in the form of expert rules extracted by AHP can be found, an answer is selected based on the input as **a** fuzzy answer. The rules have been reviewed and adjusted by the experts themselves by simulating real cases.
- The inference engine performs the task of calculating the output variables defined in 2.2.3. and 2.2.5., from the input variables and applying the fuzzy inference rules, delivering output fuzzy sets.
- Finally the response is prepared, fuzzy values are converted and actual values are obtained from the membership function of a fuzzy set.
- For the simulation, observation and analysis Matlab is used.

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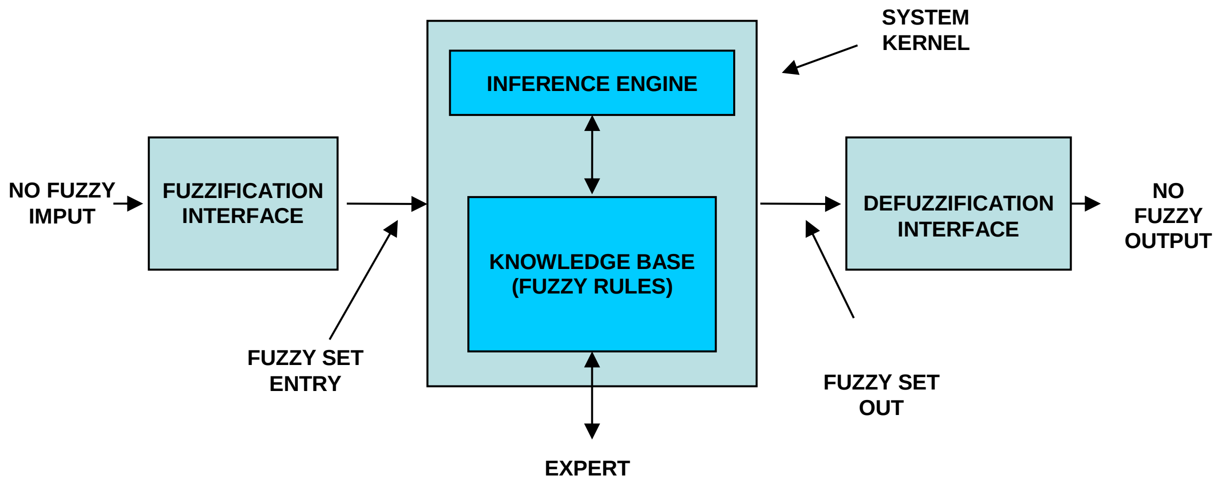

Fig. 1: "Generic Expert System" based on a Fuzzy Logic inference engine

2.2.3. Definition of input and output variables of the expert system

The National Plan of Prediction and Monitoring of Adverse Weather Phenomena, METEOALERTA [2], prepared by the AEMET, establishes the thresholds and alert levels for FMA. The meteorological risk is directly related to the "rarity" of the phenomenon, the higher it is, the less prepared the population is to cope with its effects. This system is governed by a color code:

- GREEN: no weather risk.
- YELLOW: no weather risk for the general population, but there may be risk for some particular activity.
- ORANGE: there is a significant weather risk with some degree of danger for routine activities.
- RED: the weather risk is extreme with a very high level of risk to the population.

METEOALERTA [2] divide the Canary Islands in 17 weather forecast zones. One of the major areas is formed by the eastern islands with 6 zones, and the other formed by the western islands with 11 zones. The threshold value for an FMA indicates the minimum intensity from which it is capable of causing serious personal injury or property damage.

For example, for a cumulative rainfall under 120 mm in 12 hours in a given geographical area (above the orange threshold its 100 mm), the AEMET generates an orange notice. For this specific case we work only with rainfall and accumulated rainfall, since the approach is similar to rainfall in1 hour (intensity), wind, etc..

It is recommended:

1. The warning for FMA (color-coded) is the responsibility of the AEMET, based on METEOALERTA [2]. State responsibility.
2. The information received in CECOES 1-1-2 from AEMET serves to declare pre-alert, alert or highest alert notifications by the DGSE based on PEFMA [1], Civil Protection Plan. Regional responsability.
3. Let´s now see the block diagram, which is formed by two subsystems internally cascaded (Fig. 3).

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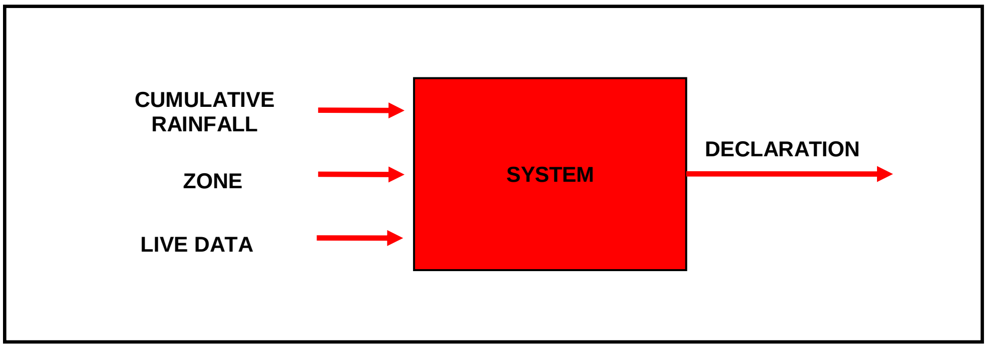

Fig. 2: "Expert System"

The system behaves as follows:

- The input variables are: CUMULATIVE RAINFALL and ZONE, provided by the AEMET; LIVE DATA, which appear when the FMA is ongoing and comes through CECOES 1-1-2.
- The output variable is DECLARATION (pre-alert, alert or highest alert) and determines a series of actions to be executed by the security and emergency services.
- In the first phase, before the FMA begins, we work only with the AEMET weather prediction, and the DECLARATION is made based on this. We must remember that fuzzy logic is effective when working with imprecision or ambiguity, erroneous data or absence of it (we still do not have actual data).
- The process begins with reception of the first bulletin issued by AEMET, and runs as many times as bulletins are received.
- In a second phase, with the FMA ongoing and fed with LIVE DATA, the system could change the status (alert or highest alert).

Internally:

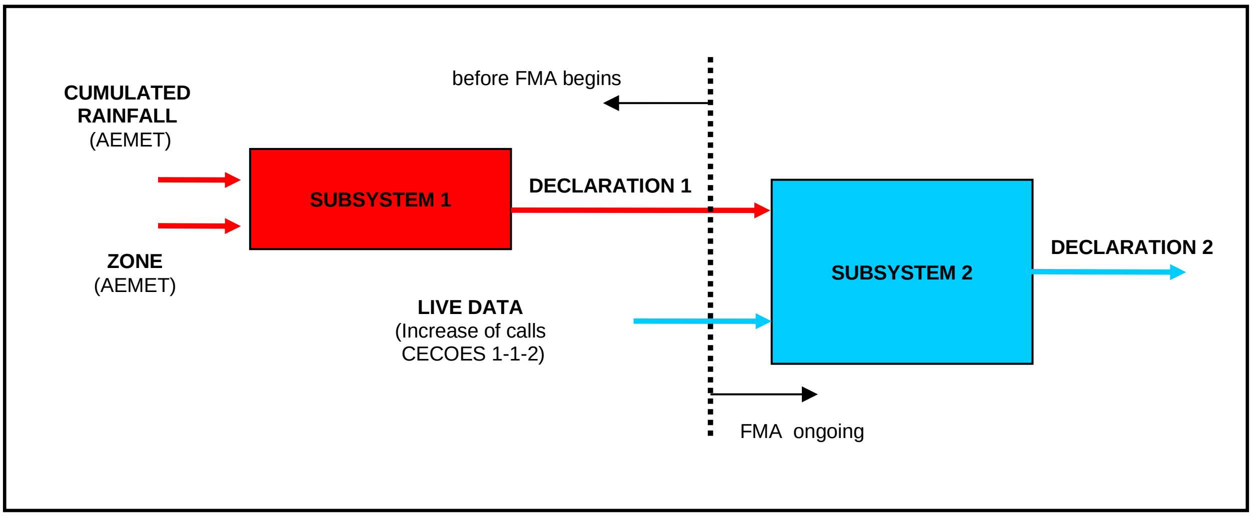

Fig. 3: "Expert System with the different Subsystems"

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2.2.4. Ranges and linguistic values of the input variables

2.2.4.1.- input variable CUMULATIVE RAINFALL

As it was stated in 2.1.2. AHP is based on obtaining importance weights for criteria and sub-criteria by pairwise comparison based on the numerical scale of Saaty (from 1 to 9). From there, local and global priorities of hierarchies are generated.

Firstly, the hierarchical model is established:

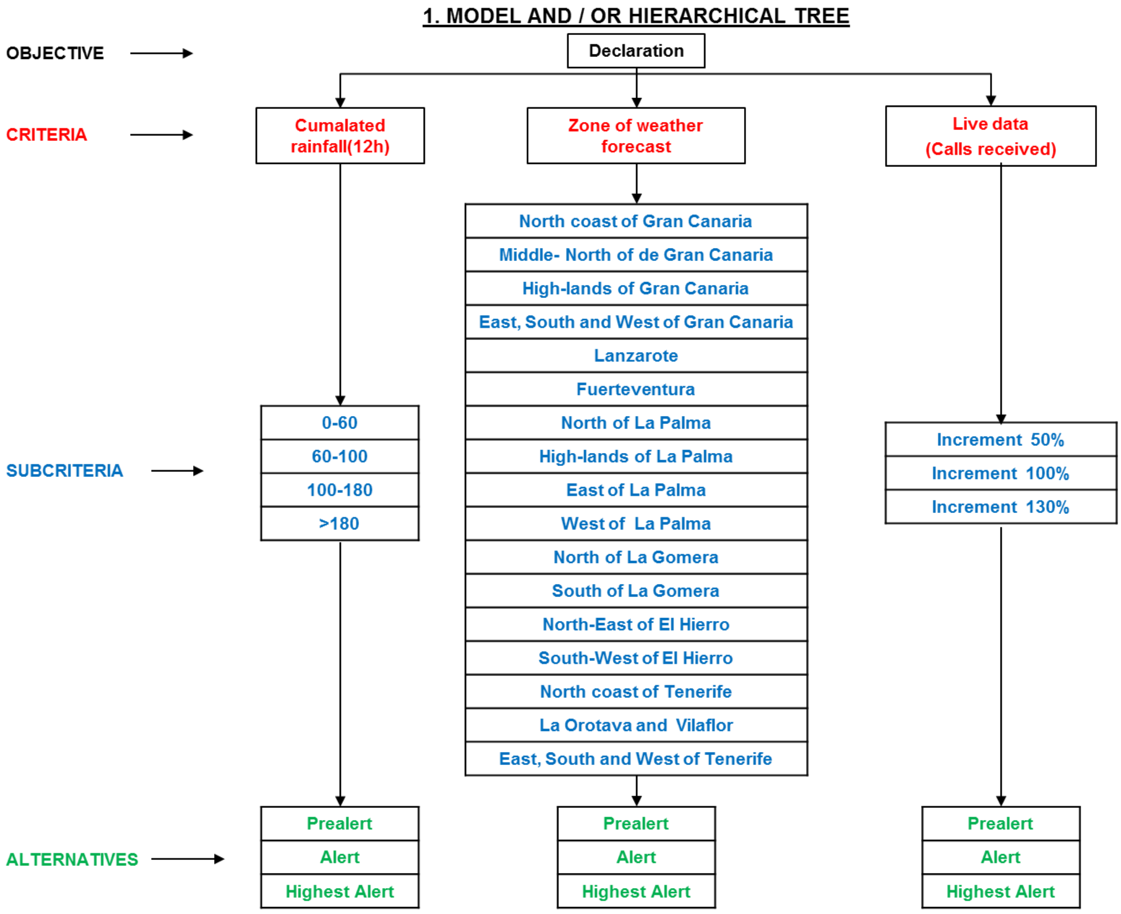

Fig. 4: Hierarchical tree.

Secondly, criteria and sub-criteria are compared in pairs:

	Cumulative rainfall	Prediction zone	Live data (calls)	Own vector
Cumulative rainfall	1/1	3/1	1/5	0,1773
Prediction zone	1/3	1/1	1/9	0,0694
Live data (calls)	5/1	9/1	1/1	0,7533

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Consistency Ratio (CR)	2,8151%	< 5%		1,0000

Table2. Pairwise comparison matrix between criteria (expert 1)

From the above matrix it can be concluded:

- Value judgments from Expert 1 are consistent. The CR is 2.8151%, which is less than 5%, maximum allowed for a matrix of rank 3.
- The weight of the live data is 75.33% compared to 17.73% of the accumulated rainfall and 6.94% of the area of prediction.
- As each expert has a different opinion, aggregation of judgements is performed with the geometric average of the own vectors generated by each one.

Third, the calculations for the different sub-criteria hanging from each of the criteria are repeated (Fig.4).

Fourth, local and global priorities are obtained. We show those referred to Rainfall criteria:

	1ª HIERARCHY (primary variables)		2ª HIERARCHY (local priorities)	Global priorities
RAINFALL	0,1773	0-60	0,0531	0,0094
		60-100	0,1148	0,0204
		100-180	0,2651	0,0470
		>180	0,5670	0,1005

Table 3. Imput variable CUMULATIVE RAINFALL

The weight of 17.73% is obtained from the pairwise comparison of different criteria (see table 2). The weights of the 2nd hierarchy are obtained by comparing the sub-criteria, and global priorities of the multiplication of the son (local priorities) by the parent (primary variables).

According to the knowledge of experts, certain areas of weather forecasting have more risk than others with identical precipitation and the two large zones behave differently.

Moreover, from the standpoint of Civil Protection, it is not the same cumulative rainfall of 100 liters on a certain area, than precipitation in the same area after a large fire. Knowledge changes and evolves and the proposed system allows for updating.

To METEOALERTA [2] the two large zones behave similarly from the viewpoint of precipitation observed ranges. Therefore, a difference between the National Plan and the opinion of the experts is detected.

To reach a greater level of detail, and observe whether the observed differences have a significant degree of consistency, a division of precipitation ranges listed in METEOALERTA [2] is done and the process is repeated again with new ranges.

An inadequate division can make us lose too much information and an excessive one can lead to increase the complexity in the domain description. Therefore, each range is divided into two, taking into consideration the National Plan and the experts' opinion.

Regarding Fuzzy Logic, remember the concept of granularity of uncertainty (see 2.1.3).

With the new division the following data are obtained:

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	1ª HIERARCHY (primary variables)		2ª HIERARCHY (local priorities)	Global prorities
RAINFALL	0,1773	40-60	0,0404	0,0072
		60-80	0,0625	0,0111
		80-100	0,0993	0,0176
		100-120	0,1594	0,0283
		120-180	0,2511	0,0445
		>180	0,3874	0,0687

Table 4. Input variable CUMULATIVE RAINFALL with an appropriate division.

When rainfall is compared with the zone for the corresponding weights, more obvious differences are observed. For the same range of rainfall, the differences between the two large areas are observable, which demonstrates the need for changing the different thresholds of PEFMA METEOALERTA. Prior to this work, the two areas were treated equally, and although no similar study had been previously performed, it was considered that the values of the two columns (zone) were exactly the same.

	Global prorities	ZONE 1 EASTERN ISLANDS	ZONE 2 WESTERN ISLANDS
40-60	0,0072	0,0003	0,0002
60-80	0,0111	0,0005	0,0003
80-100	0,0176	0,0008	0,0004
100-120	0,0283	0,0013	0,0007
120-180	0,0445	0,0021	0,0010
>180	0,0687	0,0032	0,0016

Table 5. Comparison of CUMULATIVE RAINFALL with ZONE.

At first glance, and taking into account the experts ´opinion new thresholds are proposed:

GREEN	0	<0,0003
YELLOW	=0,0003	<0,0007
ORANGE	=0,0007	<0,0016
RED	>=0,0016	

Table 6. New thresholds.

These new thresholds involve changing the National Plan METEOALERTA, and the Regional Plan PEFMA.

Once AHP has been applied, we proceed to the fuzzification process [11], to do it, truth values are converted to fuzzy values. In the system, global priorities are used as core values of the membership functions, as they represent the weight of the variable with respect to the entire hierarchy.

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IMPUT VARIABLE : CUMULATED RAINFALL (in 12 hours)			
RANGE	MEMBERSHIP FUNCTIONS	LINGUISTIC VALUE	OBSERVATIONS
40 - 60	(-10, -10, 0.72, 0.89)	P	**Little** rainfall
60 - 80	(0.79, 1.11, 1.49)	M	**Medium** rainfall
80 - 100	(1.32, 1.76, 2.30)	MA	**Medium-to high** rainfall
100 - 120	(2.01, 2.83, 3.83)	A	**High** rainfall
120 - 180	(3.45, 4.45, 5.48)	MAA	**Very high** rainfall
> 180	(5.01, 6.87, 10, 10)	ALT	**Extremely high** rainfall

Table 7. Ranges and linguistic values of the input variable CUMULATED RAINFALL

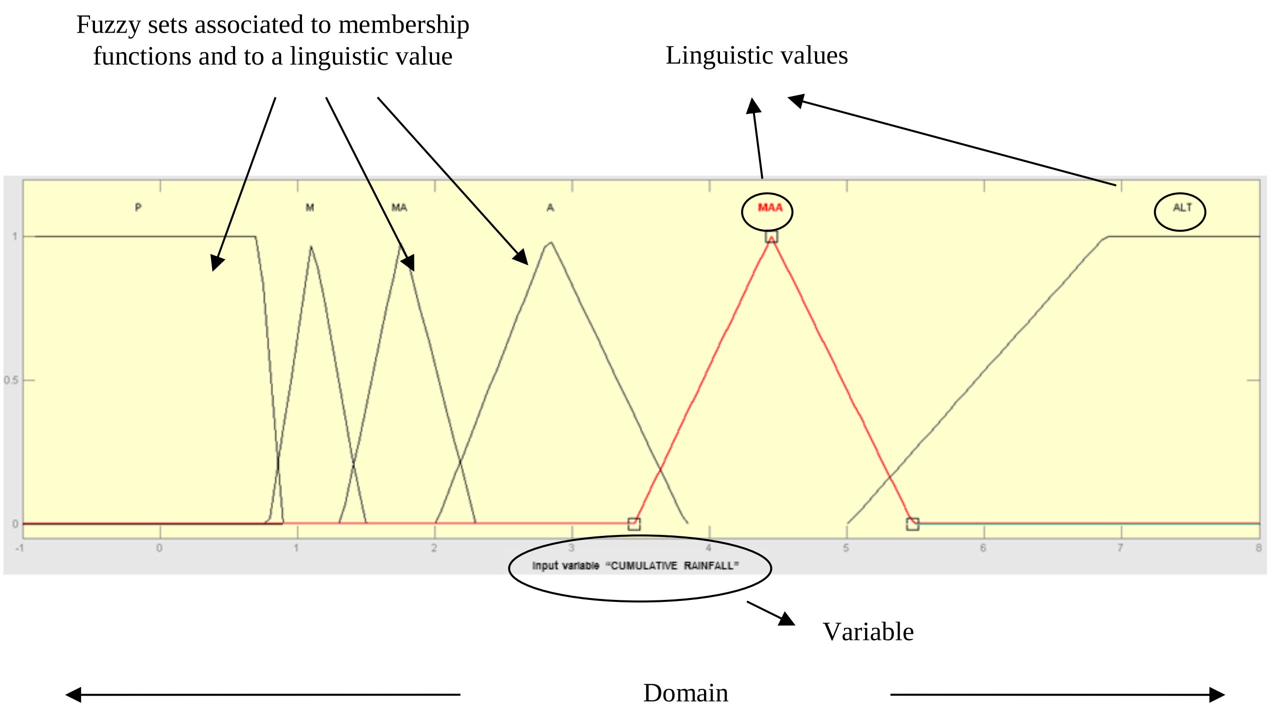

Fig. 5: Input variable, CUMULATIVE RAINFALL, with the associated fuzzy sets (MATLAB).

As the accumulated rainfall increases, the degree of belonging to a function, for example MAA, will be decreasing and increasing the degree of membership of ALT, providing gradual transition states.

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2.2.4.2.- Input variable ZONE

If the same procedure for the AREA variable is applied, we obtain the following table:

	1ª HIERARCHY (Primary variables)		2ª HIERARCHY (Local priorities)	Global Priorities	MEMBERSHIP FUNCTION
ZONE	0,0694	Las Palmas	0,6667	0,0462	(3.32, 4.62, 10, 10)
		S/C de Tenerife	0,3333	0,0231	(-10 ,-10, 2.31, 3.81)

Table 8. Variable ZONE

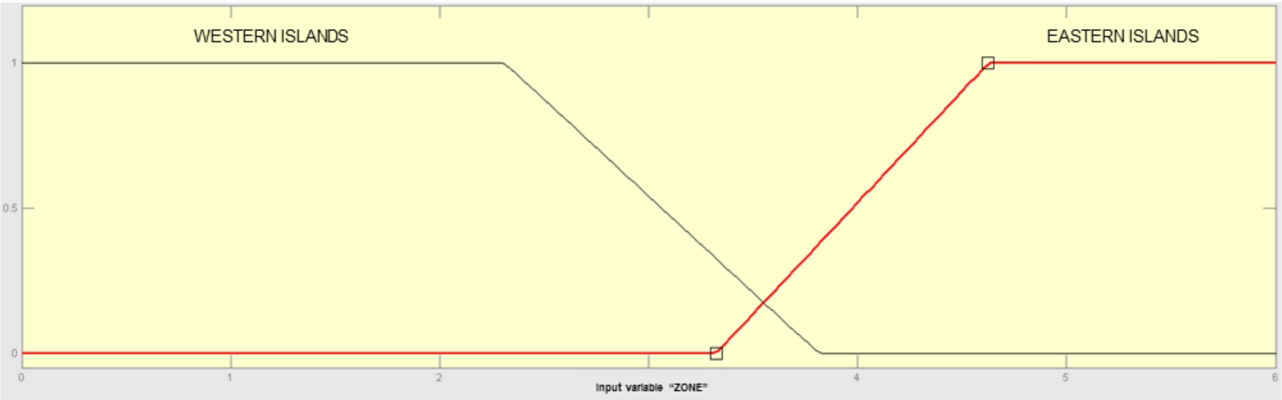

Fig. 6: Variable ZONE, with the associated fuzzy sets (MATLAB).

2.2.4.3.- Input variable CALLS

With the FMA in progress, LIVE DATA begins to appear. This new data starts feeding into the system and may cause a change of the state (alert highest- alert). The entry of this variable, with a weight of 75.33% on the remainder of the primary variables (ZONE and RAINFALL), is crucial for a change of status, in the output of the system.

	1ª HIERARCHY (Primary variables)		2ª HIERARCHY (Local priorities)	Global Priorities	MEMBERSHIP FUNCTION
CALLS	0,7533	Incremento 0-50%	0,0618	0,0466	(-10 -10 4.66 15)
		Incremento 50-100%	0,2648	0,1995	(10 19.95 34 45)
		Incremento >100%	0,6734	0,5073	(40, 50, 70, 70)

Table 9. Input variable CALLS.

2.2.5. Ranges and linguistic values of the output variable DECLARATION

The output variable stablishes a series of actions to be taken that are listed in PEFMA [1]. The membership functions are deduced from table 6.

MEMBERSHIP FUNCTION	LINGUISTIC VALUE	TASKSTO PERFORM BY THE EMERGENCY SERVICES
(-2, -2 0.03, 0.04)	NOTHING	NOTHING
(0.03, 0.05, 0.07)	PREALERT	Prealert is declared tasks according to PEFMA
(0.06, 0.11, 0.16)	ALERT	Alert is declared tasks according to PEFMA
(0.15, 0.16, 2, 2)	HIGHEST ALERT	Highest alert is declared tasks according to PEFMA

Table 10. Declarations according to range of the output variable.

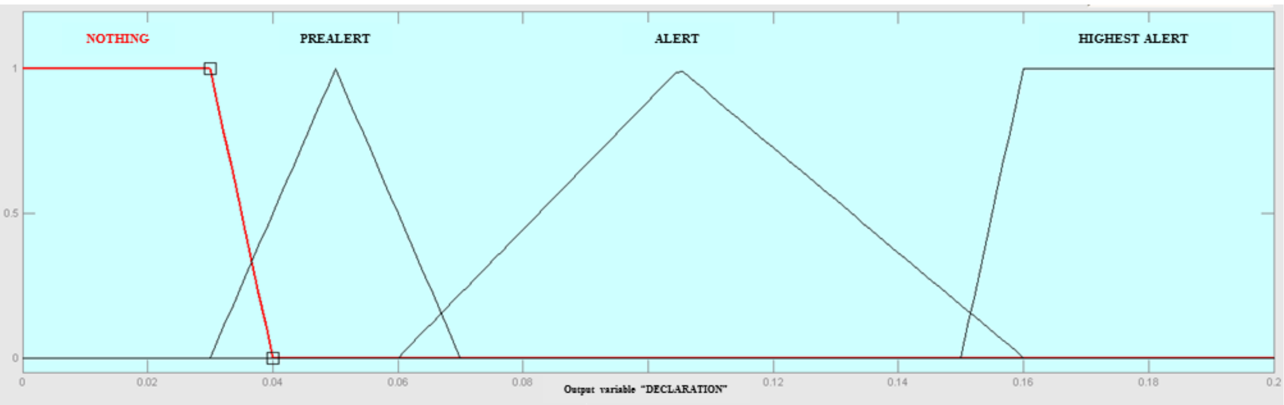

Fig. 7: Output variable. DECLARATION with the associated fuzzy sets (MATLAB).

Some time ago, there was no difference when declaring alerts, ie, all were equal in theory. In fact, some went unnoticed while others were too virulent with catastrophic consequences. But 1-1-2 CECOES staff members were reinforced in all cases, and all emergency measures were taken, which meant a waste of time and money.

Now, relying on Fig. 7, an alert with a higher degree of belonging to the set does not determine the same actions as one with a lower degree of membership. For example, when alerts with small degrees of membership occur, CECOES 1-1-2 is no longer reinforced as it was before. This allows CECOES 1-1-2 to better adapt to different weather situations

2.2.6. System validation

Two scenarios of FMA are selected and data are sought from different sources (AEMET, DGSE, CECOES 1-1-2, etc.):

1. From January 31st to February 2nd, 2010: FMA rain.
2. From 15th to 18th December 2009: FMA rain and wind.

The models, the current and the proposed one, are compared with reality occurred in two statistics: the normalized mean square error (ECMN) and the fractional bias (SF) used by Talavera and others [14].

The "Wilcoxon test" is also used to compare models.

2.2.6.1.- ECMN y SF

The output values of both models are used to compare them to the reality which occurred (observed)

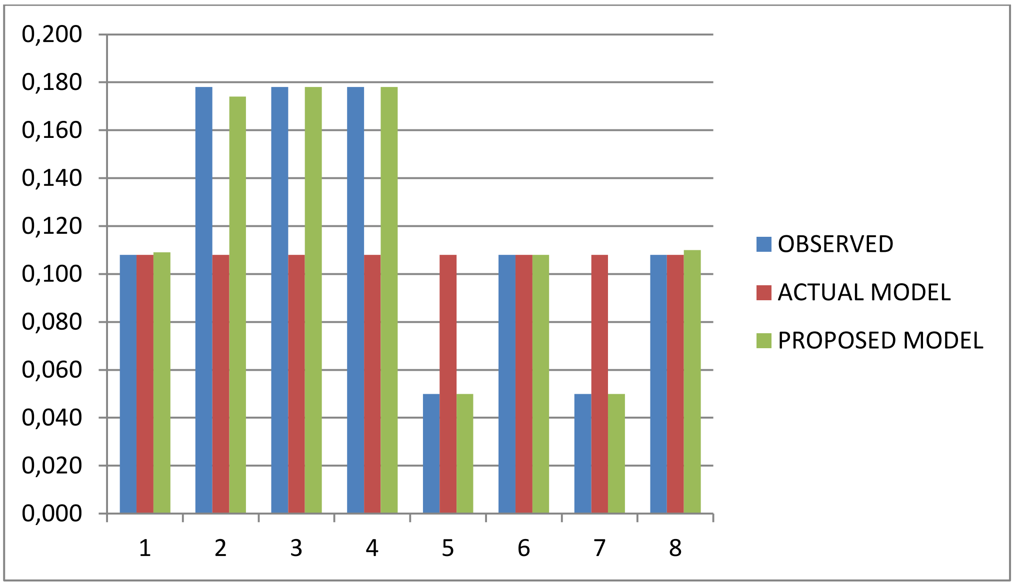

Fig. 8: Output values of both models (DECLARATION) and observed values for scenarios of FMA.

ECMN measures the accuracy of the proposed model compared to the currect one

SF shows the model trend to overestimate or underestimate

Given *n* observed values (X0) and the corresponding expected (X_p) we have:

$$ECMN=\frac{1}{n}\sum_{1}^{n}\frac{(X_0-X_p)^2}{X_0X_p}$$

$$SF=\frac{2}{n}\sum_{1}^{n}\frac{(X_0-X_p)}{(X_0+X_p)}$$

ECMN		SF	
Currect model	Proposed model	Currect model	Proposed model
0,25132	0,00012	0,00002	-0,00060

Table 11. ECMN and SF values for the current and the proposed models.

The lower the ECMN model is the more accurate, because it is closer to the reality which occurred. If the ECMN increases, the inaccuracy of the model increases.

We conclude that the proposed model is more accurate and closer to reality than the current model.

SF Negative values provide information about the model trend to overestimate, while positive values indicate a tendency to underestimate. The obtained values are not significant.

2.2.6.2.- Wilcoxon test

Wilcoxon is applied to compare the data obtained from current and proposed models with the data of reality occurred.

The null hypothesis is established (H_0):

If the differences are from a symmetric distribution around zero values W + and W- are similar, or the closer the values of W + and W- are, the closer to the reality that actually occurred.

Let´s start with the current model:

We have *n* pairs called (Xi, Yi). To test the null hypothesis, first differences must be calculated, and then, null are eliminated. Differences in absolute values are ordered $|Z1|$, ..., $|Zn|$ and a range is assigned Ri. If any of the values are repeated the midrange is calculated.

CURRENT MODEL (X_i)	OBSERVED (Y_i)	DIFFERENCES (Z_i)		DIFFERENCES (ordered by $|Zi|$)		Order/range R_i	Calculated repeated values
0,108	0,108	Z_1	0,000	$|Z_1|$	**0,000**	-	**-**
0,108	0,178	Z_2	-0,070	$|Z_6|$	**0,000**	-	**-**
0,108	0,178	Z_3	-0,070	$|Z_8|$	**0,000**	-	**-**
0,108	0,178	Z_4	-0,070	$|Z_5|$	**0,058**	1	**1,500**
0,108	0,050	Z_5	0,058	$|Z_7|$	**0,058**	2	**1,500**
0,108	0,108	Z_6	0,000	$|Z_2|$	**0,070**	3	**4,000**
0,108	0,050	Z_7	0,058	$|Z_3|$	**0,070**	4	**4,000**
0,108	0,108	Z_8	0,000	$|Z_4|$	**0,070**	5	**4,000**

Table 12.Wilcoxon values.

Now we add:

- The ranges of the positive differences or the sum of the ranks corresponding to positive values of Zi.

$$W^{+} = \sum_{Z_i>0}^{Z_n} R_i = 1{,}5+1{,}5 = 3$$

- The ranges of the negative differences or the sum of the ranks corresponding to negative values of Zi.

$$W^{-} = \sum_{Z_i<0}^{Z_n} R_i = 4+4+4 = 12$$

Since the values of W + and W- are not alike, the null hypothesis is rejected, or it cannot be said that the current model behaves the same or similar to the reality that occurred.

Now we see the proposed model:

- The ranges of the positive differences:

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$$W^{+} = \sum_{Z_i>0}^{Z_n} R_i = 1 + 2 = 3$$

- The ranges of the negative differences:

$$W^{-} = \sum_{Z_i<0}^{Z_n} R_i = 3$$

Since the values of W + and W- are equal, the null hypothesis is accepted, or we can say that the current model behaves the same or similar to the reality that occurred.

3.- RESULTS

The results originate an official proposal to modify:

1. The thresholds of METEOALERTA [2] and PEFMA [1], already modified and published.

2. The areas of weather forecasting for the Canary Islands (from 17 areas to 12) of METEOALERTA [2] and PEFMA [1], already modified and published.

It is observed that for all experts consulted, certain areas of weather forecasting have the same weight or equal influence. For example, "North coast of Gran Canaria" and " Middle -North of Gran Canaria " have the same weight for all experts when applying AHP, so that the unification of some areas into a single one is proposed in order to simplify the system.

Gran Canaria	0,6000	0,0277	North Coast of Gran Canaria	0,3716	0,0103
			Middle North of Gran Canaria	0,3716	0,0103
			High-lands of Gran Canaria	0,0917	0,0025
			East, South and West of Gran Canaria	0,1651	0,0046
Tenerife	0,4954	0,0115	North Coast of Tenerife	0,2000	0,0023
			La Orotava and Vilaflor	0,2000	0,0023
			East, South and West ofTenerife	0,6000	0,0069

Table 13. Zone with weights after applying AHP (Gran Canaria andTenerife).

Furthermore:

- The entire process is automated that was done manually and confirmed by the experts
- Decision-making is improved as to the declaration of pre-alert, alert and highest alert (see 2.2.6.).

4.- DISCUSSION

What is new is that the current model has been improved and is ready to be applied and exported, partly or completely, to any region or community. Weather forecasting from AEMET, knowledge of local experts, METEOALERTA and Civil Protection Plans designed to protect the lives and property of people, are combined in an environment of uncertainty, vagueness, and erroneous data or absence of them.

Fuzzy Logic combined with AHP creates a precise type of FMA emergency response.

Fuzzy AHP traditional methodology [11] is modified to simplify calculations with fuzzy sets. First we apply AHP to obtain the knowledge and, then, we make it fuzzy to use it in an expert system based on fuzzy logic.

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AHP is developed to gain priority of criteria and sub-criteria and with Fuzzy Logic we gain the ideal alternative.

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